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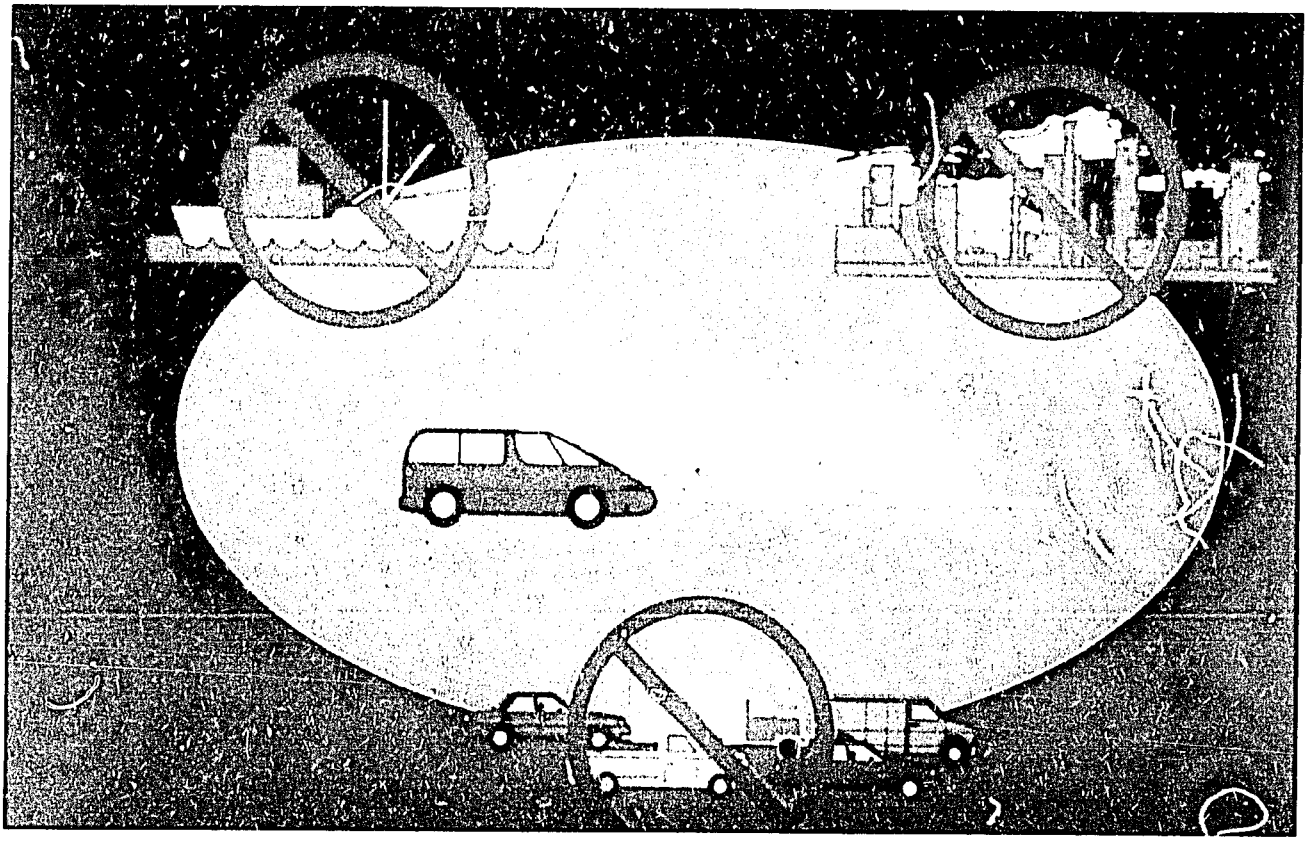
Proceedings of Indo-US Workshop on Electronic/Electric Vehicles - Technology & Policy Issues



New Delhi

April 1995

Proceedings of Indo-Us Workshop on Electronic/Electric Vehicles - Technology & Policy Issues

at

Durbar Hall, Taj Palace Intercontinental Hotel
New Delhi

February 17, 1995

Sponsored by :

* Department of Electronics - Government of India (GOI)
* Ministry of Non-Conventional Energy Sources - GOI
* Council of Scientific & Industrial Research (CSIR)
* US Agency for International Development (USAID)

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Proceedings of
Indo-US Workshop on Electronic/Electric Vehicles - Technology & Policy Issues

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Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

February 17, 1995

Program

0930-1000 hours	**Registration**
1000-1100 hours	**Session I-Inauguration** **Chairperson: Mr. Avininder Singh, Chairman CII - Renewable Energy Committee** Welcome Address by Secretary Ministry of Non-Conventional Energy Sources (MNES), Govt. of India Mr.B.R. Prabhakara Inaugural Address by Minister of State, MNES, Govt. of India Mr.S. Krishna Kumar Key Note Address by Secretary Department of Electronics (DOE), Govt. of India Mr.N.Vittal Address by Deputy Director, USAID, India Mr. Terry Myers Vote of Thanks by Director, Department of Electronics (DOE), Govt. of India Mr. R.K. Arora
1100-1120 hours	**Tea Break**
1120-1400 hours	**Session II Technology** **Chairperson: Mr. B. D. Bose Chairman, Birla Enston** **Overview of Role of Electronic/Electric Vehicles (EVs) in Transportation** Electric Power Research Institute (EPRI), US Ms. Veronica Rabl **Battery Development** Chloride Industries Ltd., India Dr. S.K. Mittal, Executive Vice-President (R&D) Central Electro Chemical Research Institute (CECRI), India Dr. R. Gangadharan, Head, Battery Division Ovonic Battery Company, US Mr.Subhash Dhar

Electronic Drive Development

Central Electronics Engineering Research Institute (CEERI), India
Mr. V.N. Walivadekar
Senior Assistant Director

Eddy Current Controls, India
Mr.M.D.Jos
Managing Director

Case Studies

Case Study I
Advance Electric Car Technology (AECT), US
Mr.Charles Haba

Case Study II
Unique Mobility Inc., US
Mr.John Everton

Case Study III
Bharat Heavy Electricals Ltd., India
Mr.P.D. Gupta, Sr. Deputy General Manager
and
Mr. H.K. Gupta, Sr. Deputy Manager

Discussions and Recommendations

1400-1500 **Lunch**

1500-1700 **Session III-Policy Issues**

Chairperson: Mr.U.N.Panjiar
Joint Secretary, MNES

Fiscal Instruments to promote EVs in India

MNES, Government of India
Mr.A.K.Gayen, Director

Policies to promote EVs in India

MOEnF, Government of India
Dr.S.C.Maudgal, Senior Advisor

Consultant-Peerless, India
Mr.A.N.Shukla

Rationale and Applications of EVs in India

Chatelec Vehicles (I) Limited, India
Ms. Shanta Chatterji, Vice Chairman and Executive Director

Perspectives on Electrical Vehicles-
View Point of an Automobile Manufacturer

Bajaj Auto Ltd., India
Mr.Tapan Basu, Senior Manager

Discussions and Recommendations

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

Executive Summary

The important issues of concern today in the automotive sector are environmental pollution and energy conservation. Several steps have been taken the world-over to address to this issue. One of them is to enlarge the application of electronic technology in automotives. A significant step in this direction has been to introduce Electronic/Electric Vehicles (EVs) which are pollution free eco-friendly vehicle with zero emission.

In India also, these issues assume significant importance in view of the alarmingly increasing rate of pollution due to automobiles in our metropolis and the need to conserve fast depleting oil resources. In pursuance of national strategy for finding alternative sources of energy for surface transportation, under a sponsored project of MNES, BHEL in 1980's developed 18-seater, 1-ton pay load battery operated electric vehicle. To promote the operation of electric vehicles, under a national demonstration programme of Battery Operated Vehicles (BOV), the purchase of BOVs is subsidised by MNES. This subject has been attracting the attention of the Government of India from different points of view of technology, economy, fiscal, market etc. for promoting EVs. An Inter-agency Steering Committee, convened by the Department of Electronics, with members from Ministry of Non-conventional Energy Sources, Ministry of Environment and Forests, Ministry of Surface Transport Department of Industrial Development, Council of Scientific and Industrial Research etc., concerned industries and other experts in the field, has been examining these issues. The Committee has suggested setting up of a Consortium of the Government and the Industry to promote EVs in India and develop technologies which will help in the speedy introduction of techno-economically viable EVs.

Critical technologies involved are High energy density batteries and Electronic drives. The fiscal issues are tax exemptions and flexibility in licensing EV operators. Besides, there are issues such as awareness creation and legislation which require attention. There also appears to be a good market for EVs in India. Ministry of Surface Transport has already amended Motor Vehicles Act to provide flexibility in route and tariff to EV operators. Ministry of Non-conventional Energy Sources has been giving subsidy to EV operators. Additional tax exemptions are also being considered by the Government. Earlier BHEL, a public sector company, has introduced about 200 EVs, but recently more manufacturers, viz., Chetelec, Eddy Current Controls, Peerless etc., in the private sector, have come in to introduce EVs for industrial applications and as passenger cars. Developments are also progressing at other industries and CSIR laboratories. The Consortium proposed would develop synergy with these developments.

The need for EVs in India is well recognised. A combination of regulatory support from the Government in promoting EVs, and efforts by the industry to meet the challenge and use the opportunity so created will go a long way in implementing a satisfactory EV programme in India. It is also an opportune time as many other countries are having similar programmes. India may, therefore, be able to develop niche markets for export of EVs once fully developed.

To discuss these issues, an Indo-US Workshop was held on 17th February, 1995 in New Delhi during the CII ENCON-95. Altogether about 160 participants covering over 50 different organisations attended the Workshop. 15 different papers, including 5 from the US, covering technology and policy issues were presented and discussed.

In his opening remarks, Mr. Avininder Singh, Chairman of the CII-Renewable Energy Committee, promised industry's active role in developing EV industry. In his welcome address, Mr. Prabhakara, the Secretary of the Ministry of Non-conventional Energy Sources, highlighted the importance of development and use of EVs in India to meet the twin objectives of conserving petroleum fuel and reducing environmental pollution. He informed about the sustained efforts taken by his Ministry since 1980's for the development and promotion of electric vehicles. Mr. Krishna Kumar, the Minister of State for Non-conventional Energy Sources, inaugurated the Workshop. He laid emphasis on the use of Non-conventional Energy Sources to reduce the burden of import of fossil fuel and reduce environmental pollution due to the automobiles which use petroleum fuel. He affirmed the commitment of the Government in encouraging use of EVs to meet these objectives. Mr. Vittal, Secretary, Department of Electronics, in his keynote address, informed about the work that has been done through an Inter-agency Steering Committee of the Government and the Industry in this area. He suggested that there was a great potential for use of EVs in India since India perhaps has the richest incidence of solar energy and a large population creating a significant domestic demand for such vehicles.

The session on Technology covered the status of developments in the areas of High Energy Density Batteries and Electronic Drives, which are the two important inputs for making viable EVs. In this context, the developments in the area of Insulated Gate Bipolar Transistor (IGBT) and Metal on Surface Field Effect Transistor (MOSFET) based drives using both DC motors as well as AC motors, and more recently the switched reluctance motors were discussed. In the area of Batteries, development in Nickel Metal Hydride batteries were presented by a US company. Also developments in the conventional Lead Acid Battery and other technologies such as Sodium Sulphur, Fuel cells, Nickel Cadmium etc. were discussed.

The Session on Policies covered the present situation with regard to the incentives offered by the Government in terms of subsidy on purchase and tariff. The proposals for further concessions in this area and the amendments to the Motor Vehicles Act to provide incentives to the operators were discussed. A few case Studies were also presented highlighting the governmental policies and experience in India, Thailand and the US in both 2/3 wheeler and 4 wheeler EVs. The current programmes of introduction of EVs in India by the Industry and the need for greater government and industry interaction and participation to encourage speedier introduction of these vehicles were discussed in detail.

The Workshop led to a number of recommendations in the various connected areas. These are highlighted below:

i. Electric Vehicle is a physically viable product today. However, it is yet to be made economically viable. Further, since it is not cost effective at the moment, the interest from the traditional auto-manufacturers is lacking. Therefore, a favourable environment and certain incentives are needed to make EV manufacture attractive to the industry. Thus, for example, tax reduction on EVs and its imported parts, tariff concessions for EV operators, softer loans to the industry and appropriate legislation to create good market for EVsare urgently required.

ii. There is a large market for 2/3 wheelers in India which incidentally is also the major source of pollution. The other major source of pollution is the commercial vehicles. These should therefore be looked at from the point of view of conversion to EVs. In this context, considerations may be given to introducing pollution tax, accelerated depreciation for EVs and schemes for deploying certain percentage of vehicles of EVtypeby service/utility organisations and large industries employing movement of goods and people in their premises.

iii. There is a need for an attitudinal change so as to overcome the mental block in terms of initial cost of EVs, their necessity and applications in a number of areas and long term advantages of operating thesevehicles. This can be done through such steps as demonstration in certain identified areas, concept marketing, improving environmental awareness, interaction with outside agencies, suitably

modified Motor Vehicles Act etc.

iv. The work in the direction of both introducing legislation with Government Incentives and technology development in EVs is going on simultaneously in practically every Western country, notably in the US. France, Germany, Italy, UK and Japan. Since the importance of EVs applies to India as well, this is the time to take lead in introduction of EVs by way of such legislations and technology development in India to keep pace with other developed countries.

v. There is a need to create a forum in which both the Government and the Industry interact very closely to consider each others' needs and contribute to the deployment of such EVs in the quickest possible time. Such an integrated effort would go a long way in ensuring that viable technologies are available, industry interests are developed and the market is also created to sustain such efforts.

vi. The other specific suggestions/recommendations emerged are:

a. The pricing of conventional fuel like petrol and diesel should include external and invisible costs such as environmental cost, national economic security cost.

b. Motor Vehicle Act to allow banning of fossil fuel vehicles in identified areas, such as National Parks, Monuments and Tourist resorts.

c. Formation of a Consortium of concerned Ministries/ Departments and the manufacturers of EVs, batteries and SPV modules etc. for facilitating a coordinated approach for the formulation of policies and development of EVs.

d. Fiscal incentives such as exemption of excise duty and customs duty on EVs, batteries and their components. Like other renewable energy equipments/systems, 100% depreciation for the purchasers of EVs should also be allowed.

e. Provision of concessional loans to the manufacturers of EVs.

f. Liberalised import of the latest technology, as regards the design, development and fabrication of EVs.

g. Support for development of EVs, high energy batteries, their components and technologies by the industry and the Government.

h. The EV operators to be allowed to fix the tariff as per their cost of operation and be exempted from road tax etc.

i. Ministries, large industries, service organisations, State Electricity Boards, Electric Supply Corporations etc. should be exhorted and encouraged to go in for purchase of EVs in a coordinated and time-bound manner so that at least 10% of their fleet of vehicles consists of EVs by 2000 AD.

j. As charging in the off-peak hours is beneficial, concessional tariff for electricity in off-peak hours is recommended.

k. Energy conservation agencies, like Petroleum Conservation Research Association, Energy Management Centre, Ministry of Environment and Forests should also consider providing funds, alongwith MNES, as subsidy for purchase of EVs.

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

Inaugural Session

Summary of Address

Mr. Avininder Singh
Chairperson

In the introductory remarks, Mr. Avininder Singh, Chairman of the Inaugural Session, welcomed the participants to the Workshop on Electronic/Electric Vehicles and gave a brief introductory background of holding the Workshop. He stated that several experts from US, engaged in the manufacture of EVs had been invited for the workshop, and hoped that several key personnel from Indian industries and R&D institutions will share their experiences in this area. He promised active role of the industries in developing EV industry in India.

Welcome Address

Mr. B. R. Prabhakara
Secretary
Ministry of Non-Conventional Energy Sources
Government of India

Hon'ble Shri Krishna Kumar, Mr. Myers, Mr. Vittal, Mr. Avininder Singh, Ladies and Gentlemen,

It is a matter of great pleasure and proud privilege for me to welcome Shri Krishna Kumar, Minister of State for Non-Conventional Energy Sources & Agriculture, Mr. Myers of USAID, India, learned speakers who have come all the way from USA and different parts of India, worthy guests and delegates to this workshop.

The topic of the workshop is very relevant in today's circumstances of continuous depletion of petroleum fuels required for transportation needs and growing alarming situation of urban air pollution created by burning of fossil fuels. In pursuance of national strategy for finding alternative sources of energy for surface transportation, MNES, under a sponsored project of Bharat Heavy Electricals Ltd. (BHEL) in 1980s developed 18-seater, 1 ton payload Battery Operated Electric Vehicles. Later on in 1994 under a joint project of MNES-BHEL, the latter developed 40-passenger Battery Operated Bus which is at present under trial runs. BHEL entered commercial production of 18-seater battery vehicles in 1980s. Besides BHEL, some private entrepreneurs have also entered manufacturing and marketing battery operated electric vehicles, both passenger and industrial models. Battery Operated Vehicles demonstration programme was introduced by MNES in 1986 with the main objective of providing suitable alternatives to Petrol/Diesel vehicles with a view to conserve oil and to provide pollution free and noiseless means of surface transport. Under the Battery Operated Vehicle Demonstration Programme, capital cost subsidy is sanctioned by MNES to various organisations and State nodal agencies. As a result of the demonstration programmes valuable experience has been gathered by Government, vehicle manufacturers, users, and sub-component manufacturers. This has resulted in the endeavour of the vehicle manufacturers and associates in perfecting various sub-system technologies of Electric Vehicles such as chopper controller, battery, charger, motor, etc. USA has been taking keen interest in the development and promotion of EV's as the same are zero emission vehicles. This has prompted the state of California to regulate that 2% of all vehicles must be EVs by 1998. Some US organisations and companies are here to present their experiences to you. This workshop will provide a forum for mutual sharing of US and Indian experiences in the field of battery vehicle and exchange of ideas regarding critical points, like range, speed, High Energy Density battery and other operational parameters and various other relevant points like promotional policies etc. I once again welcome Hon'ble Chief guest, members of USAID, US organisations, Indian organisations and delegates to this workshop. I am sure that all the participants would take keen interest, participate in the deliberation and discussion from which meaningful and practical recommendations will emerge.

Inaugural Address

Mr. S. Krishna Kumar
Union Minister of State for Non-Conventional Energy Sources & Agriculture
Government of India

Mr. Avininder Singh, Chairman, CII, Renewable Energy Committee, Mr. Terry Myers, Dy. Director, USAID, India, my colleague and Secretary MNES, Mr. B.R. Prabhakara, Mr. N. Vittal, Secretary, Department of Electronics, Mr. R.K. Arora, Director, Department of Electronics, distinguished delegates, members of the press, Doordarshan and friends.

It gives me great pleasure to be in the midst of such a distinguished gathering of scientists, engineers and representatives of industry, participating in the "**Indo-US Workshop on Electronic/Electric Vehicles - Technology and Policy Issues**" the first of its kind in Delhi. I would like to compliment the organisers Department of Electronics, CSIR, USAID and MNES for convening this landmark workshop in Delhi at an appropriate time when the world is poised for a great leap forward in the field of renewable energy for sustainable, balanced and environment friendly economic development.

The world oil supplies could perhaps last only for another 75 years, those of natural gas for 150 years and coal for 250 years or more. While these are global figures, the actual energy situation in many individual countries, particularly oil-importing developing countries is quite serious. With 6 billion tonnes of carbon emissions each year, global warming at unprecedented rates, danger of acid rain and climate changes not to speak of the finite and exhaustible nature of the fossil fuel resources, it is clear that the end of the fossil fuel age is in sight and the transition to a solar energy economy has begun. Only a few decades remain with us to redirect and restructure the world energy economy. In this inevitable process of historic transition renewable energies will move progressively to the centre stage of the energy mix and energy policy of the developed and developing nations of the world.

Rapid growth of heavy industry and near quadrupling in number of automobiles outside western industrial countries - from 22 million in 1970 to more than 109 million in 1991 have caused steady deterioration in the air quality of virtually all third world cities. Each unit of electricity produced by coal leads to emission of around 1.5 kg. of carbon dioxide and other gases into the atmosphere. Breathing the air in Bombay is now the equivalent of smoking 10 cigarettes a day. In Bangkok which has 2 million automobiles and thousands of factories, a million people were treated for respiratory problems in 1990, lead poisoning in lowering the measured intelligence of children and lung cancer is three times as common as in the rest of the country.

All this brings us to the truth that for development to succeed, it has to be sustainable. And a sustainable energy basis is a must for such development. This has been brought out in the conclusions of the Rio Conference on environment and the global programme that emerged from it. It is now recognised that the world will have to make a transition from an economy based on hydro carbon to one based on renewable sources of energy.

Oil shocks of 1973, 1979 and 1990 have exposed serious risks inherent in an energy dependent situation and brought to sudden focus energy management strategy based on research and innovation of energy efficient technologies, design optimisation and maximisation of energy conversion and generation, diversification of resources and promotion of local energy sources. Thinking of all these factors makes us wonder whether this kind of growth based on conventional energy supplies can indeed be sustained. The unsurmountable oil crisis in this country coupled with incessant and unabated increase in the pollution level in most of our cities due to vehicular smoke and toxic emissions have led the development and introduction of battery powered smokeless, noiseless, oil free, electric vehicles which employs no internal combustion engine and no oil to operate. Instead it is run by an electric motor which inturn gets motive

power from a power pack of rechargeable traction batteries positioned on the vehicle itself. The power transmission takes place through the conventional gear box and differential. Speed is controlled by an Electronic Thyristor Chopper Controller and gear changing. In all other respects such as steering, brakin, gear box and clutch arrangements etc. Electric vehicles are similar to conventional diesel or petrol vehicles and therefore need no extra training t drive them. For commuter service, batteries withdrawal arrangement is provided with facilities for removal discharged batteries and fitting of charged ones within few minutes at the battery charging stations.

Electric Vehicles usage is being increasingly favoured to fight the menace of air pollution in Urban areas, Industries and Institutions.

The advantages of electric vehicles are:

* Conservation of petrol/diesel with consequent saving of precious foreign exchange.
* Energy efficient systems as it does not use energy when standing on red signals or getting loaded or unloaded and gives better drive efficiency.
* Less maintenance cost and breakdowns because of the absence of large number of moving parts like pistons and cylinders etc.
* Pollution free as no unpleasant smell or toxic emissions. It therefore helps to keep the living/working environment clean, quite and hygienic.
* Longer life because of the absence of engine vibrations since electrical equipments are being used.
* More passenger comfort as these are jerkfree and smooth ride.

As a scientific and technical achievement electric vehicles came into existence during 1890s By 1898 there was rapid growth of electric vehicles. They were operated in large number in New York, London, Paris & Berlin etc. During 1899 to 1920 about 33000 registered vehicles were available in USA alone. During 1920 to 1930 due to rapid advancement of IC engine technology and low oil prices, electric vehicles were put in oblivion. During 1973 Electric Vehicles were again revived due to oil crisis. Newsland, Japan, United States, United Kingdom, Germany, France and Italy has carried out good work in the field of battery powered vehicles. India has also developed its first prototype in 1980. During 1981 to 1984 Bharat Heavy Electricals Ltd. under a sponsored project of my Ministry has designed and fabricated 10 Nos. of prototypes of electric vehicles of 1 ton pay load capacity. M/s. Eddy Current Control Ltd., Coimbatore has developed battery operated passenger car. At present 3 manufacturing base have been established in the country for manufacture of industrial and domestic models.

Battery Operated Vehicles demonstration programme was introduced by MNES in 1986 with the main objective of providing suitable alternatives to Petrol/Diesel vehicles with a view to conserve oil and to provide pollution free and noiseless means of surface transport. Under the BOV Demonstration Programme, capital cost subsidy is sanctioned by MNES to various organisations both public/private/ government sector and State nodal agencies.

India may be one of the first countries in the world where running of Electric Vehicles are operated by various organisation like Punjab State Electricity Board, National Park, Bharatpur, Lakshadweep Administration, Madhya Pradesh Electricity Board, Non-conventional Energy Department, Lucknow, Pallavan Transport Corporation, Madras, etc.

The objective of the demonstration programme is to get performance of the vehicles under actual running demonstration programmes valuable experience has been gathered by Government, vehicle manufacturers, users, and sub-component manufacturers. This has resulted in the endeavour of the vehicle manufacturers and associates in perfecting various sub-system technologies of Electric Vehicles such as chopper controller, battery, charger, motor, etc. A BOV Shuttle Mini Bus Service was started in July, 1989, between

CGO Complex and North Block via different Government buildings at New Delhi for use by the Government officials for their official works. the service is very popular to the Government employees. It has served more than 11 lakh employees.

Transport Development Council in its 23rd meeting held on 19.1.93 have recommended amendment of relevant provisions of MV Act so that the private transporters can be allowed to obtain permit for running BOVs from point to point basis and allow operators to charge such tariffs as per the market support. Government is pursuing the recommendations.

Industrially developed countries have taken up the challenge of meeting the twin problems of continuous depletion of finite fossil fuels and pollution created by vehicular transportation. United States of America has always been on the forefront for the development of electric vehicle. Manufacturers like GM, Ford, Chrysler, Motorola and many others are developing viable EV technology. The State of California has passed a regulation that 2% of all vehicles sold must be EVs by 1998. In several places like baltimore, Boston, Howai etc. battery operated electric vehicles are being demonstrated. In coventry (UK), Milan (Italy), Barcelona (Spain), and Tours (France), Evs will be available on rentals. In USA developmental works have been taken up for heavy duty battery also Despite tremendous achievements in the field of development of EVs, it is facing various difficulties like Heavy duty battery, chopper controller, etc. In a comparative study of total life cycle cost of 5 different types of vehicles such as Gasoline, M-85, CNG, Elctrics and Hybride, the Capital Operating Salvage (COS) cost of EV is 35% higher than gasoline vehicle. The COS cost, if the environmental cost is considered, EV is 33% higher than Gasoline vehicle. Hence the matter is to examine whether paying higher capital costs for advance technology with low operating and low environmental cost is advantageous over paying lower capital cost for conventional technology with higher operational and environmental cost.

Reducing the fuel-related threats posed by motor vehicles will require the gradual substitution of ZERO EMISSION VEHICLES (ZEVs) for internal combustion vehicles over the next few decades. Such an approach will have both short and long-term elements. In the longer term, ZEVs will have to be phased in powered by sustainable sources of energy-including wind, solar power or hydrogen derived from renewable sources. A ZEV will emit much less pollution and carbon dioxide than even the cleanest internal combustion engine

The transition of ZEVs will take three to four decades. For atleast the next ten years, zero emission vehicles will mean battery powered vehicles. Ultimately, ZEVs will be powered by some combination of batteries, hydrogen fuel cells, flywheels, and ultra capacitors.

Electric vehicles will help the world make the inevitable, long-term transition to reliance on sustainable energy sources. Sizable benefits could be realized within 20 years if these new technologies were phased in aggressively. Moreover, if current goals for performance and cost can be met, these benefits could be achieved for about what the nation seems willing to pay to achieve the same results using other means.

One of the most important single action that could be taken to accelerate the introduction of zero emission vehicles would be to reform pricing of gasoline and diesel fuel. Even though the seemingly straightforward move of raising fuel taxes is in practice fraught with political and conceptual difficulties, these costs are real and ought to be reflected, however imperfectly, in the price of fuel at the pump. According to one rough estimate, U.S. motor vehicle drivers impose nearly $300 billion per year more in costs on society than they pay directly themselves. Of these, some $70 billion are related to air pollution, climate change, imports, and noise - all products of oil combustion. This translates of about $0.50 for every gallon of gasoline and diesel fuel consumed by American cars, trucks, and buses, and several researchers have concluded that increasing fuel prices by about this amount would be enough to make advanced battery and fuel-cell powered vehicles cost-competitive with oil-powered vehicles on a life-cycle basis. Stated differently, without higher oil prices, consumers - atleast initially - are not likely to see the purchase of electric vehicles to be in their own economic interest. In the absence of politically unpopular price reforms, these regulations

serve as a vital technology-forcing mechanism to bring electric vehicles into the market place.

Beyond pricing reform is a need to develop EV technology further. Increased shared-cost research into promising batteries, fly-wheels, ultra capacitors, fuel-cell designs, and hydrogen production and storage technologies would increase the odds that one or more of these technologies will become commercially viable. Without improved energy storage higher energy densities, longer life-cycles, and lower costs electric vehicles will remain expensive short-up urban vehicles, useful for commuting and errands but far from all-purpose vehicles. Nickel-metal-hydride and lithium batteries are very promising, but other batteries (such as nickel-hydrogen, zinc-air and aluminum-air) and fuel cells, also deserve increased support, as do the ultracapacitors and flywheels needed to help meet the high energy demands of vehicle acceleration.

Electric Vehicles, whatever their power source, will require a widespread system of standardized recharging facilities or hydrogen pipelines, compressors, battery-recycling centers, and other equipment. Normally daunting, standardizing new technologies is even harder when the status of emerging technologies is changing as rapidly as it is now. Continuing advances in on-board energy-storage devices makes early standardization perilous and potentially costly, but without agreement on storage and refueling technologies, it will be difficult to introduce these new technologies widely. Carefully designed demonstration programmes, especially with fleets, could being to dismantle these barriers, identify the most promising technologies, and help get more electric vehicles on the road.

Another pressing need is for more research on systems integration and optimisation to identify the best way systems integration and optimisation to identify the best way to put the various pieces together. Battery and hydrogen vehicles could be introduced into our transportation system in various ways, particularly if we refuel them using such renewable energy technologies as photovoltaic cells or wind machines. But where and how should these vehicles be refueled? Where and how should the energy from the renewable sources be transmitted and stored? What are the economic, safety, and reliability tradeoffs of various configurations? These questions must be answered through careful systems analysis and optimization before policy-makers can be expected to choose among the many forks in the road.

As recharging/refueling standards are adopted, building codes for residential, commercial, and industrial facilities should be modified to make new buildings "EV compatible". Initially, federal tax incentives or grants could be provided to demonstrate the use of photovoltaic arrays for EV battery-recharging at public or business parking lots.

Also needed are more trained personnel to deal with electric vehicle. Emergency professionals (fire, police, paramedics require training to deal with accidents involving electric vehicles. On this front, DETROIT Edison is already working with U.S. automakers to develop a video, manuals, and pocket guides for emergency personnel. Incentives to fleet owners can stimulate the market for battery and hydrogen electric vehicles. If incentives meant that even one tenth of these vehicle were EVs - 100,000 cars per year - electric vehicle manufacturers would have a robust market.

Under the Clean Air Act Amendments of 1990, of United States some 150,000 alternative fuel vehicles must be sold in the pilot state of California beginning in 1996 and 300,000 per year by 1999. The law also required the introduction of alternative-fuel vehicles in other states that don't meet clean air standards. Because of the marginal benefits offered by vehicles burning methanol, ethanol, and compressed natural gas, these fleet purchase programmes should focus mainly of ZEVs - battery and hydrogen fuel-cell electric vehicles.

Tax credits and hydrogen fuel-cell established by the Energy Policy Act on 1992 in USA for both the purchase of electric vehicles and the construction of recharging stations. In addition, the new transportation law, the Intermodal Surface Transportation Efficiency Act (INSTEA) in USA provides unprecedented flexibility to local and regional authorities in transportation planning - in principle, affording the opportunity to integrate electric vehicles into the U.S. transportation system.

Other measures could hasten the introduction of EV-friendly infrastructure. Grants could be provided to municipalities that install charging meters of PV-charging arrays at publicly owned facilities. The government could adopt a "Green Car" programme to showcase companies buying and using EVs in their fleets. State public utility commissions (PUCs) could permit utilities that adopt time-of-day rates for Evs to include in these rates the costs of installing ZEV-recharging equipment at homes and offices.

They could also permit utilities to own and lease EV batteries to consumers - a measure that would overcome the barrier of high battery-cost and ensure battery recycling.

State and local vehicle fees and taxes - including annual registration fees, sales and personal-property taxes, and fuel taxes - could also be reduced or waived for a fixed introductory period, perhaps five years. Some kind of "feebate" arrangement like those designed to promote fuel-efficient cars could be used to subsidize the purchase of electric vehicles. Reduced local and state taxes, together with feebates, batery leasing and the current federal tax credit, would go a long way toward easing the transitional problem of high first-costs faced by EV purchasers.

A remaining need is technological : standardised driving cycles should be adopted so that consumers can more accurately guage the efficiency of electric vehicles under realistic driving conditions. Much like the federal driving cycle used for gasoline-powered vehicles, this would allow potential buyers to easily compare the relative performance of various types of vehicles.

The substitution of electric cars and trucks for oil-powered vehicles will cure a major part of the nation's transportation ills. But still to be resolved are the troubles born of sprawl and congestion. For these, the answer lies in creative combinations of zoning, land-use planning, and the introduction of other emerging transportation technologies, such as personalized rapid transit.

Phasing-in battery - and hydrogen-electric vehicles would be an evolutionary leap toward a sustainable transportation system, one that will neither depend on depletable energy resources nor endanger human health or the environment. As these vehicles begin to appear in numbers, we will begin to see air pollution outside and national security improve. Once we

complete the parallel introduction of renewable sources of electricity some time in the next century, we will have taken a giant stride toward protecting the earth's climate as well.

May I take this opportunity to reiterate that the manufacture and marketing of electric vehicles bears immense potential for entrepreneurship and good business. The central Government has expressed is total support to those engaged in translating its plans into reality. The Government is open to new ideas, suggestions and discussions for removing any impediments.

With these words, I take pleasure in inaugurating the Workshop and wishing the function all success.

Thank you

Jai Hind

Key Note Address

Mr. N. Vittal
Secretary
Department of Electronics
Government of India

Can India be a leader in Electric Vehicles

1. There was a frog which was in a well and wanted to get out. It appealed to various passers by to help it to get out. Many declined the request of the frog. There was one sympathetic passer by who agreed that he would help the frog to get out of the well, but as he was busy with some work, he would return after half an hour to help the frog to get out.

2. When the kind passerby returned after half an hour, he found the frog had already come out of the well. The passerby asked the frog: How is it that all these years you could not get out of the well and when I had promised you to come within half an hour to help you, you had managed to get out." "Oh! said the frog. You see, there was a poisonous snake on the well trying to attack me and I had no alternative, but to jump out!"

3. When I look at our Indian condition, so far as transport vehicles are concerned, I am afraid that we are in the condition of the frog in the well, without even having a conscious idea that we should get out of the well. We all know that petroleum is a resource which is not going to be available for all time to come. Sooner or later alternatives to petroleum as a fuel have to be found. Further we also know nearly 65% of the pollution in cities is caused by automobiles. In the light of the growing awareness about pollution and the need for ensuring healthy environment, alternatives have to be found.

4. There was a worldwide anxiety to develop alternatives to petroleum after the 1973 oil shock administered by OPEC. But as soon as the problem of the shock was overcome and the petroleum prices came down again, generally there is a slackness in the effort to find alternative fuel for transport vehicles.

5. The Automotive Industry plays a key role in the economic development of a society, as it serves an important instrument of communication infra-structure. The availability of fuel efficient, safe and pollution free automotative transport is in fact and index of the health of a developed society. Electronics has been increasingly used to achieve fuel efficiency, improved safety and reduced emission in automotives.

6. By far, the two important issues of concern today in the automotive sector are environmental pollution and energy conservation. Attention of the world therefore has lately been drawn in the direction of developing automotive industry which does not pollute and which is fuel efficient. Some statistics in this context are :

   * Transport consumes 35% of the total fuel.

   * It has high as high as 85%, potential for fuel saving.

   * 65% of the environmental pollution is caused by road vehicles.

7. Several steps therefore have been taken by the industry the world over to address to this major issue. One of them is to use electronics technology in improving the fuel efficiency of the conventional petrol/ diesal driven vehicles,

8. A quick review of the status of development of EVs by various industries in the world reveals that virtually every major automotive manufacturer has a programme for EVs. The enclosed chart (Annexure-1) reveals this. It is therefore realised that this technology is expected to drive the automotive industry in future. Besides, there are other manufacturers of the electric power utility systems, battery manufacturers etc., who are contributing to the development of EVs.

9. In every developed country, Government have also played an promotional role in developing its industry. For example, in USA an US Advanced Battery Consortium (USABC) has been set up as a Consortium of the Government and the Industry involving US $ 260 million to develop technology of advanced batteries for this system. The governemnt is also introducing various concessions such as tax credits for EV purchasers and subsidising installation of charging facilities etc. In USA it has also been mandated that 2% of the vehicles in California would be of EV type by the year 1998. It will increase to 5% by the year 2001 and 10% by the year 2003. This would mean EVs in excess of 100,000 manufactured and sold by the last year of this decade.

10. In Japan, similarly, MITI has planned for the introduction of approx. 200,000 vehicles by the year 2000 and 100,000 vehicles every year thereafter. The Task Force of MITI and Japanese auto manufacturers has been set up which is looking into the mechanism of meeting the requirement of EVs, and the battery development.

11. In other European countries such as Germany, France and Italy, similar development efforts for the EVs. and the batteries are taking place. The Government is introducing such measures to aid the increased use of EVs. as exemptions, permission to operate in special areas etc. In Germany for example programme of DM-150 million for development and testing of EVs and the batteries was instituted.

12. In India also we have initated action through different Ministries, so far as development of electric vehicles are concerned. The Department of Non-conventional Energy has been providing subsidy for electical vehicles. The Department of Surface Transport has come with a scheme for exempting the electrical vehicles from normal licensing conditions regarding selection of route etc. The Transport Advisory Committee also has made similar recommendations and these have been communicated to all State Governments. The Ministry of Petroleum has been encouraging the use of alternatives to petroleum like liquid natural gas etc. The Department of Environment also has been highlighting the negative aspects of pollution caused by automobiles.

13. The department of Scientific Industrial Research and CEERI Pilani has also been funding research for converting an Ambassador car to run on batteries only. The Karaikudi Central Electrochemical Research Institute has been working on batteries.

14. Under the Rules of Business, the subject of automobiles is with the Department of Industrial Development. The Department of Electronics took the initiative in 1993 to form a steering committee of all concerned departments to explore the alternatives.

15. The issues discussed cover economy, technology, fiscal and market for promoting EVs in India. It is recognised that such vehicles are not commercially attractive today and therefore the conventional auto manufacturers by themselves would not take the lead. Therefore, it has to be viewed as a programme of the Government in which the industry participates to implement taking advantage of the favourable fiscal and financial regime provided over by the Government. In fact, the manufacturers of electric power companies and the batteries have shown considerable interest to develop EVs. These efforts need to be supported so that the deployment of such vehicles can increase by large proportions beyond what has been the position so far.

16. Already, BHEL have taken a lead to put EVs on a limited scale. Other manufacturers in the private sector such as Chetelec, Eddy Current, Peerless have also come in the field for passenger and industrial vehicles. A few other manufacturers have also built vehicles of EV type for special applications. Battery manufacturers are also gearing to build suitable high energy batteries for EVs. Thus, there is already a considerable familiarity of EVs among the manufacturers in India.

17. The two important technologies in the EVs are the battery and electronics drive, which together decide the range and cost-performance of the EVs. Many battery technologies have been promoted and intensive developments are in progress. A quick review of the development status worldwide for the batteries for EVs is given in Annexures II and III. It appreas from this that lead acid battery which is the main stay of EVs today will have to give way to other technologies to improve the range performance. Promising technologies are Nickel Metal Hydride, Sodium Sulpher and Fuel cells. As many of these batteries are still under development abroad they would be very expensive to buy from outside. Hence, it is prudent that India also undertakes development of sme of these technologies taking advantages of experience of industry and the laboratories in India, and the lead from experience outside.

18. Another technology which is important for the EVs is electronic drive. Here again several technologies are available. These are for example

    i. DC motor, AC motor or SRM motor

    ii. Drives using MOSFET or IGBT technology

    It will be desirable to develop suitable drives for the vehicles used in India as capability of the drive is dictated by the requirement of the vehicles. Here again our expertise in the industry and the development laboratories can be made use of.

19. As regards the fiscal and other incentives, amendment to the Motor Vehiicles Act have already been made, allowing route and tariff flexibility to the EV operatores. Already subsidy is also being gibvven by the Ministry of Non-conventional Energy Sources to EV users. Efforts are also in progress to provide tax concessions to the EV users and manufacturers.

20. As regards the market in India, following are the applications envisaged:

    * Movements in large industrial estates
    * Utility Services such as postal delivery vans, municipal services etc.
    * Applications in airports and large tourist parks
    * Short to medium range vehicles belonging to large organisations
    * Pick up vans for passengers, cargo, repair and maintenance services etc.

21. A techno-economic comparison made by some of our EV manufacturers in operation of EVs is given in Annexure IV and V. From this it appears that even though initial cost of EVs may be high compared to petrol/diesel driven vehicles, in the long term, looking at the operating expenses, the EVs may score better over conventional vehicles. Even internationally, it has been shown that the cost of an EV less its battery, compares favourably well with the cost of a conventional vehicle. This, therefore, again lays down thrust on development of cost effective batteries. Arrangements for leasing of batteries etc. could also be considered to reduce burden on capital costs.

22. In consideration of this subject in India, it has been suggested to form a Consortium of the Government and the Industry. This will enable the Government to extend requisite support to the industry and the industry to gear themselves to produce techno-economically viable vehicles. It will also focus on

issues such as creating awareness about the use of EVs, organising the logistics of maintenance, battery charging etc. and create a suitable environment for the industry ot introduce vehicles in the market. The following other issues have also been considered and are receiving attention:

* Specifying certain percentage of vehicles to be of EV type used in certain sectors.
* Identifying certain clean air island areas for deployment of EVs.
* Regularly review fiscal concessions for the manufacturers and encourage the operators to use EVs.

23. The need for use of EVs in India has been well recognised. It is an effective mechanism of conserving our fast depleting oil and reducing alarmingly increasing pollution in our metropolis. To meet these twin objectives, the Government and the Industry should hold each other's hand and produce techno-economically viable EVs in India. A combination of force and support from the Government in developing suitable EVs, and efforts by the Industry to meet the challenge and use the opportunity so created will go a long way in implementing a satisfactory EV programme in India. It is also an opportune time as many other countries outside are also having similar programmes. We may therefore be able to develop niche market outside for export of EVs once developed here.

24. The Steering Committee came with a proposal that what was needed was a consortium of all the concerned departments and the industry to fund innovative research and development. The issue is pending for a decision at the government level.

25. I mentioned some time back about the frog's story. It will be obvious to any thinking Indian that being dependent on petroleum products is not going to be a solution in the long term. It is better that we think of alternatives right away. We also know that we cannot expect the automobile industry to be very enthusiastic in this case. It is true that in the United States, California State is making it mandatory that atleast 2% of the vehicels by 1998 should have zero pollution. The General Motors, Chryster and Ford are putting their efforts together to develop electrical cars. But we must realise that in business the substitutes and alternatives have generally come from those who were not in that business. I am sure, the person who invented the automobile was not a person who was running horsedrawn vehicles. The person who invented the printing press was not the person who was a great caligraphist. It is obvious that no business will commit harakiri by inventing a substitute. The initiative has to come from outside.

26. Secondly success will come to those who can create the future. This is the point argued by C.K. Prahalad and Hammel in their book 'Competing for the Future'. The future is not going to depend on those who are on top of the traditional businesses today, but who are able to find new methods and new substitutes and create a competitive space.

27. India has also a demographic advantage in the sense that with a population of 900 million and with 200 million middle class, there is a growing demand for vehicles. The very fact that the automobile sector is booming, thanks to the governemnt economic liberalisation policies and many new companies are also getting into automobiles should also alrert us to the fact that we will be placed in a vulnerable position, if we do not have fuel to run the vehicles. Does it make a sense to us ten years from now to have a large number of automobiles which will all be stranded, because we do not have fuel? Retrofitting of the existing automobiles will be a costly proposition.

28. In fact, the approach to the electrical vehicle is dependent on three main aspects. The first is of course developing a very effective battery which will be lasting for a longer time between charging. The second is developing effective electronic drives. The third issue is that the whole design in automobiles will have to be done de novo instead of taking the existing automobile and trying to retrofit the battery in the existing structure. That is why I mentioned that alternatives to our fossil fuel driven vehicles will come from those who are not in the automobile business.

29. As a country, we must be able to put money in this and develop competitive advantage in this area. Japan is a small country where the space is at premium, and naturally the Japanese automobile industry focussed on smaller vehicles. This will be obvious from the book 'Against All Odds' which gives the history of Toyota. Because there was hardly any domestic market and survival was the problem, countries like Singapore, Taiwan have developed into great exporting countries. In India, we are required to develop electrical vehicles for the simple reason that we cannot afford to be totally dependent on import of petroleum, which in anyway will run out after some time. Secondly the investments which are now being made in automobiles should also be successful.

30. The frog jumped out of the well, because the snake was about to attack it. Are we going to jump out into electrical vehicle only when we find that our atmosphere has become polluted beyond control and our vehicles are all likely to grind to a half because we are running out of sources of petroleum? It is always a good idea to start digging a well, before there is any fire. So now is the time to start seriously thinking about the electrical vehicle and see also whether India can develop a core competence for leading the rest of the world in the 21st century in the electrical vehicles. A look at the advantages India enjoys should make us automatically think in this direction.

    i. We have perhaps the richest incidence of solar energy in the world, because we have probably more than 250 days of sunshine every year The solar energy should make us think in terms of using better resource instead of petroleum, because it is obvious that ultimately the energy that will drive the economy during the next century onward is going to be solar energy.

    ii. We have a large population of 900 million which will very soon cross above billion and therefore there will be a very large domestic market for vehicles.

    iii. We are perhaps not very much behind others, so far as this area is concerned. Therefore, this is one area where we do not have to play the game of catch up. Is it not desirable that for a change, India leads instead of trying to continue perpetually in the game of catch up?

Electric Vehicle Development Programme - Major features at a glance

S.No.	Vehicle Name and Type	Developing Agency	Type of Battery Used	Range (Km)	Max. Speed (kmh)	Status & Remarks
1.	Volkswagen City Stromer (Passenger Car)	Volks Wagen Ag. Germany	Lead/Acid Sodium/Sulpher	140 120	104	70 EVs using Lead/Acid Battery sold. Based on Jetta production vehicle.
2.	Mercedes-Benz 190 EV (5 Passenger Car)	Mercedes Benz Ag (Germany)	Sodium/Nickel Chloride	150	120	Research Car uses to external roter DC Motors.
3.	Electro Microcar (Passenger car)	Auto Technik Walther Gm BH Germany	Gelled Lead-Acid	60-100	75-90	Available in three models. Solar panel optional.
4.	Tepco IZa (4 Passenger Car)	Tokyo Electric Co., Japan	Ni/Cd	550 at 40 Km/h	176	Only one car built to prove concept. Uses 25 KW brushless DC Motor inside each wheel.
5.	Nissan FEV (Passenger Car)	Nissan Motor Co., Japan	Nickel Cadmium	160 at 72 Km/h	120	Concept proved. No production plans yet. Can accept a 40% charge in 6 minutes, has solar cells in commercial fleets.
6.	G-Van (Passenger/ Cargo Car)	General Motor (USA) Electric Power Research Institute (EPRI), Conceptor Industires Inc, Canada	Lead/Acid	96 (City Driving)	83	Based on GN glider. Uses a 43 KW dc motor. About 100 EVs in service in commercial fleets.
7.	Mini-el City (3-Wheeler)	City com A/s Denmark	Lead/Acid	30-35 (City)	40	Being sold in Denmark, Switzerland, Sweden and Germany. Also introduced in Norwa, Netherlands.

8.	Renault Zoom (Passenger Car)	Renault (France) Matra SA France	Nickel Cadmium	150	120	Concept proved Production version under development.
9.	Fiat panda Elettra (Passenger Car)	Fiat SpA Italy	Lead/Acid Nickel/Cadmium	80 City Driving	113	Production run of 500 EVs planned. Uses a 9.2 KW DC series motor.
10.	Pollicino Etabeta (Urban Bus)	Carrozzeria Autodromo Modena Italy	Lead/Acid	50	55	Also makes special vehicles, mini-buses
11.	Smile Lady (Passenger Car)	Coop Car/ Microwet Italy	SAEH	35-45	80	Available with solar panel.
12.	LA 301 (2 passenger hybrid Car)	Los Angeles Deptt of Water & Power, South California Edision Co. Clean Air Transport USA	Lead/Acid Sodium/Sulpher	96 154	97	Commercial production projected for 1993. Hybrid version with sodium/Sulpher battery and petrol engine has range of 240 km.
13.	Monterey (Passenger Car)	California Electric Cars Inc., USA	Lead/Acid	100 City	110	Production began in 1991
14.	Doran Electric (3-Wheeler)	Doran Motor Co., USA	Lead/Acid	102	136	Production began in August 1991.
15.	TE Van (Passenger/ Cargo Mini Van)	EPRZ, Chrystr Corp., USA. Southern Edison Co., USA	Ni/Iron	180	105	Based on Chrysler Minivan glider, uses a 46 KW dc Motor. About 50 EVs will be produced in 1993.
16.	Ecostar (Mini Van)	Ford Motor Co., USA	Sodium/Sulpher	160	120	Based on Ford's European Escort 80-100 EVs will be produced in 1993 and leased for 30 months.

						Uses a 3 phase 56 KW AC Induction motor integrated into front transrade.
17.	BMW E/E (4 Passenger Car)	BMW AG (Germany) Unique Mobility USA	Sodium/Suopher	240 (at 90 Km./h)	120	(E Concept Proved). No production plans announced. E Model uses a 32 KW permanent magnet DC motor.
18.	GM Impact (2 Seater, Sports Car)	General Motors, Aero-Vironment Inc., USA	Lead/Acid	190 (at 90 Km./h)	120	Commercial production planned for mid 1990s. Uses two 43 KW AC Induction Motor.
19.	VW Minibus (9 Passenger)	Spijkstaal Spijkenisse Holland	Sodium/ Sulpher	200	106	Being manufactured since Nov. 1991.

Basic Types of Batteries & their Developing Agencies

Battery	Developer
Lead Acid	Chloride GB, Varta Germany, Delco Remy USA, Johnson Controls USA, Yuasa Japan, Electroscope USA, RWE Germany
Nickel Cadmium	SAFT France, Hoppecke Germany, Japan Storage, Yusa Japan
Nickel Iron	Eagle Picher USA, Farukawa Japan, SAFT France
Nickel Zinc	Yusa Japan, Istocknick Russia
Zinc Bromine	Meidensha Japan, SEA Austria, Johnson Controls USA
Sodium Sulphur	Yuasa Japan, RWE (Chloride) GB, ABB Germany
Sodium Nickel Chloride	AEG Germany, Beta R & D GB
Lithium (all types)	Valence USA, Hydro-Quebec Cananda, Harwell Lab GB, US Dept. of Energy, Innocell Energy Denmark, Yuasa Japan, Varta Germany, SAFT France, Eagle Picher USA, ENEL Italy
Nickel Metal Hydride	Ovionic USA, Yuasa Japan, Matushita Japan, SAFT France, Varta Germany, Eagle Picher USA
Zinc Air	Dreisbach Electromotive USA
Aluminium Air	Alupower

Comparision of various Battery Systems under development for EVs*

Battery System	Type of Electrotye	Energy Denisty (Wh/kg)	Peak Power (Wh/kg)	Energy Efficiency (%)	Cycle life	Self discharge (% per 48h)	Cost US $/kwh
Acidic Aqueous Solution							
Lead - Acid		30 - 50	70 - 130	>80	50-1500	0.6	70 - 130
Zinc - Bromide		70 - 80	35 - 100	75	200-2000	40	150 - 300
Alkaline Aqueous Solution							
Nickel - Hydrozen		60 - 70	300	70	2000 *	6	700 - 2000
Nickel - Iron		40 - 60	80 - 150	60	500 - 2000	3	200 - 1400
Nickel - Zinc		55 - 85	170 - 260	70	500	1.2	200 - 500
Aluminium - Air		220 - 300	160	<50	?	?	?
Iron - Air		100	90	60	500 *	?	50
Zinc - Air		120 - 200	30 - 80	60	600 *	?	110
Molten Salt							
Sodium - Sulphur		100 - 140	130 - 180	85	800 *	0	110
Sodium - Nickel Chloride		90 - 130	60 - 130	?	1000-2000	?	?
Lithium - Iron Sulphide		60 - 130	100 - 200	80	1000 *	?	110
Solid State							
Lithium/Composite		85-130	?	80-85	100 *	0.03	100

* Based on laboratory experiments on prototyes

? Not known

Annexure - IV

Techno Economic Comparison
Between 18-Passenger Electravan & Identical Diesel LCV

(As in April 1993)

Sl.No.	Particulars	Electravan (EV) (Rupees)	Diesel LCV (DV) (Rupees)
1.0	Ex-works cost	4,87,500	-
1.1	Total cost with ED & ST	5,27,230	-
1.2	Cash subsidy	1,00,000	-
1.3	Net cost	4,27,230	2,58,000
1.4	Less Depreciation Benefit (EV : 100% DV : 33.3%)	1,79,440	72,000
1.5	Less salvage cost	48,700	25,800
1.6	Add cost of capital (12% on 75% of 1.0 for 5 yrs.)	2,19,400	2,70,900
1.7	Net fixed cost (1.3 -1.4 - 1.5 + 1.6)	4,21,000	4,31,100
1.8	Fixed cost/year	34,875	61,600
2.0	Yearly run (KMs)	19,800	19,800
3.0	Energy cost/year	19,800	13,900
4.0	Battery replacement cost/year	23,700	900
5.0	Maintenance	7,900	19,800
6.0	Operating cost/year (3.0 + 4.0 + 5.0)	51,400	34,600
7.0	Total cost/year (1.8 + 6.0)	86,275	96,200
8.0	Total cost/KM	4.35	4.86
9.0	Saving per KM on Electric Vehicle	0.51	

Basis of T.E. Comparison

1.	Interest Rate	:	EV - 12% DV - 21%
2.	Run/Day	:	60 KMs
3.	Utilisation	:	330 Days/yr.
4.	Diesel Rate	:	Rs.7.00/ltr.
5.	LCV mileage	:	10 KMs/ltr.
6.	Elec. Tariff	:	Rs.2.00/KWHr
7.	Life	:	EV - 12 yrs. DV - 7 yrs.
8.	Salvage Value 5% for batteries	:	EV & DV - 10%
9.	Battery Life	:	3 yrs. (3 sets replacement in 12 yrs.)
10.	Maintenance cost	:	EV - 40% that of DV

Techno Economic Comparison between Electric Tow Tractor/ Platform Truck Substituting Diesel Industrial Models

Sl. No.	Parameter	Electric Vehicle Rs/Km	Diesel Rs/Km
1.	Fuel Rs.1.5/Kwh 27 Kwh per charge		
	30 km run per charge	1.35	1.72
2.	Maintenance Rs. 650 pm 600 km run per month	1.09	2.25
3.	Insurance @ 1.5 & per km in an year	0.62	0.18
4.	Depreciation	0.83	0.35
5.	Total cost/km	3.89	4.50
6.	Savings per km on Electric/electronic Vehicle	0.61	

Vote of Thanks

Mr. R. K. Arora
Director
Department of Electronics
Government of India

Thank you Mr. Singh for giving me this opportunity to perform a pleasant task of giving a vote of thanks. Before I do that, I would like to apologise for the inconvenience that may have been caused due to the last minute change in the venue of this workshop from Pragati Maidan to this place.

I would like to begin by first thanking all of you; my friends, colleagues, representatives from various industry organisations and the EV professionals who have gathered here from various parts of the country and the USA to attend this Workshop. I would then like to place on record my sincere appreciation to all the sponsoring organisations - the USAID, the MNES, the CSIR and my own Department, the Department of Electronics, for heartily joining hands to make this Workshop a success. Special thanks are also due to JPS Associates and RCG/Hegler Bailly for their untiring efforts for preparations in all aspects of this Workshop.

I would then like to express our sincere thanks to Mr. Prabhakara, the Secretary-MNES who, inspite of a very short time of his coming to the scene, accepted to be here to give a welcome address. My special thanks are due to my own boss Mr. Vittal, Secretary, DOE, for his very forceful and encouraging keynote address. As you all know he has taken special interest in this subject as the Chairman of an Inter-agency Steering Committee to promote EVs in India. He is currently piloting the setting up a Consortium of the Government and the Industry to further develop and promote EVs in India.

I would like to take this opportunity to specially thank Mr. Myers and all his colleagues in USAID who, inspite of a less than a month's time for this Workshop, readily agreed to support organisation of this Workshop and arrange to have experts from 5 different organisations in the US, who are currently very intimately involved with the EV development programme in US, come to India.

Lastly, but most importantly, I on my own behalf and on behalf of all my colleagues in MNES, CSIR, DOE and USAID wish to say thank you very much Sir! Mr. Krishna Kumar, Hon'ble Minister of State for the Ministry of Non-conventional Energy Sources. He has been a constant source of encouragement for developing this programme in India.

This is amply shown by the fact that inspite of his pressing engagements during the day he readily agreed to spare time to come and deliver the inaugural speech.

Last but not the least, I wish to thank the Press and Doordarshan for covering this event.

Well, we have come to the close of this inaugural session. Thank you Mr. Singh again and the CII for offering to organise this workshop under ENCON-95 during the Indian Engineering Trade Fair. I request all of you to join for a cup of tea. We will assemble here again at 11.30 hours.

Thank you al once again!

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

Summary of the Proceedings of the Inaugural Session

The Inaugural session was chaired by Shri Avininder Singh, Chairman, Renewable Energy Committee of CII. Welcome Address was delivered by Shri B.R. Prabhakar, Secretary, MNES. The key note address was given by Shri Vittal, Secretary, Department of Electronics and Shri S. Krishna Kumar. Hon'ble Minister of State for Non-Conventional Energy Sources & Agriculture delivered the Inaugural Address.

In his Welcome Address, Shri Prabhakara, expressed gratefulness to the Hon'ble Minister of Non-Conventional Energy Sources & Agriculture for making it possible to address the gathering inspite of his very busy schedule. It reflects how much importance the Minister attaches to the use of non-conventional energy sources which are non-polluting and environmental friendly. Today the automobile industry is totally in the hands of fossil fuel and to change over to any other mode is apparently a very difficult task. He however, stressed that Government of India is determined to go for the change and switch over to the Electric Vehicle from the conventional fossil fuel driven vehicle system. He assured and emphasised that this alternative method, if adopted, would go a long way in the control and abatement of pollution caused to the heavy human population all over the world, particularly in the developing

countries like India. He mentioned that while the population has increased in a ratio of 1:3 a period of 4 decades in India, vehicle population has gone up to a ratio of 1:300. During 1951, the vehicle population in India was 0.3 million whereas at the end of 1994, it stood at 30 million. Moreover the adoption of Electric Vehicle also conserves the depleting resources of oil. The importance of the Electric Vehicle has now been recognised all over the world which itself is highly commendable and a very healthy sign. The theme of the present seminar on Technology and Policy Issues is very timely and he was sure that workshop will come out with concrete proposals on the option of Electric Vehicle.

The Hon'ble Minister in his Inaugural Address congratulated the Department of Electronics, MNES, CSIR and USAID for sponsoring such a seminar. He mentioned that the Government of India under the dynamic leadership of the Hon'ble Prime Minister Shri. P.V. Narasimha Rao is fully committed to development of renewable sources of energy to counter the problems posed by the conventional sources. It is a part of government's strategies to support programmes which are directed to use alternate sourcesof energy and combat abatement of pollution. It is clear that fossil fuel based economy will have to pave way for renewable sources of energy or solar energy based economy.

Therefore, the workshop addressing to development of Electric Vehicle is very timely. Indian and US Governments, in the framework of joint cooperation, have already accorded high priority to areas of renewable sources. India is fully committed towards development of electric vehicles which uses alternate sources of energy rather than fossil fuel. Department of Electronics in association with concerned research laboratories & industries has already launched many programmes in this direction and though task is not easy, still, if concerted efforts by all the concerned are made, this can be achieved. It is the endeavor to save future generation and provide them with clean environment. The present generation has to sound the decision makers that they are seized with the problems and are determined to overcome the obstacles progressively.

The Minister further informed that some progress in India is already made and India will be further benefited by the experience of countries which have already ventured in this direction. US has made substantial progress in technology of EVs. India would like to have the best technology wherever it is available and

all the support in this direction will be provided. He hoped that appropriate policies and strategies will be forthcoming from this workshop. The mandatory legislations, if any, and the fiscal incentives in achieving the objective would be committed from the Government. Mr. Krishna Kumar wished the conference the very best success and expected that this will be a landmark in the development of Electric Vehicle in this country.

In his Key Note address, Shri Vittal, Secretary, Department of Electronics mentioned that although the topic of the Workshop is Electronic/Electric Vehicle, the basic idea is to have a transportation system of electronics and electrical energy. He mentioned that the two important issues of concern today in the automotive industry are environmental pollution and energy conservation. Efforts of the developing and developed world are, therefore, emphasised in developing automobiles which are fuel efficient as well as non-polluting. Many steps have been taken by the industry to address these issues and one of them relates to using the electronics technology in improving the fuel efficiency of the conventional fossil fuel driven vehicles, improving their safety and reducing the levels of environmental pollution caused by them. The Electric Vehicle is virtually a zero emission vehicle. In India, interest in developing such vehicles has been evinced for quite some time. However, concerted efforts have recently been made through joint programmes by industry, R&D institutions and government. He highlighted issues regarding promotional role played by the developing countries and gave an example of USA where Government has introduced various concessions such as tax credits for EV producers and subsidising installation of charging facilities, and mandatory battery provision of 2% of the vehicle manufacturers being electric by the automotive industries, particularly in California. This percentage will go up by the end of the century. Similarly, in Japan and other European countries such as Germany, France and Italy, development efforts on similar lines are taking place. Obviously, the governments are concerned in these countries to quickly replace polluting vehicles by non-polluting vehicles ie. EVs.

He mentioned that the concern which the Hon'ble Minister has already expressed has beseized the Government and the government is fully committed to develop and manufacture EVs in the country through joint programmes between Industry, Government, R&D institutions and Battery Manufacturers.

India is fortunate enough to have a lot of advantages in developing such a vehicle viz; large solar energy incidence, large domestic market for vehicles and the gap in technology which is not very wide. He congratulated the organisers for choosing such a timely theme and expected that policy issues in developing electronic/electric vehicle will be addressed to and at the end of the workshop, a direction will be set in development and manufacture of electric vehicles in India.

Mr. Myer of USAID in his address mentioned about the efforts of US Government in developing Electric Vehicle and the concern for supporting such programmes in developing countries. He offered bilateral technical assistance between USAID, CII, Government of India and other agencies, India would be one of the major countries in developing electric vehicles. He also mentioned that a few of the distinguished personnel from US automotive industries have been invited to share their knowledge with the august body and he hoped that the workshop will gain from the experience of US.

Mr. R.K. Arora from the Department of Electronics in his Vote of Thanks mentioned that the participants and distinguished speakers in various sessions would help in generating enthusiasm in development of EV in the country and very presence of all these people reveals concern on the issues which the Workshop would be addressing. he particularly thanked the sponsorors, namely, Ministry of Non-conventional Energy Sources, CSIR, USAID, and Department of Electronics, and supporting agencies viz. JPS Associates, Management Consultants, New Delhi and RCG/Hagler Bailly Inc., USA.

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

Technology Session

Summary of Address

Mr. B. D. Bose
Chairperson

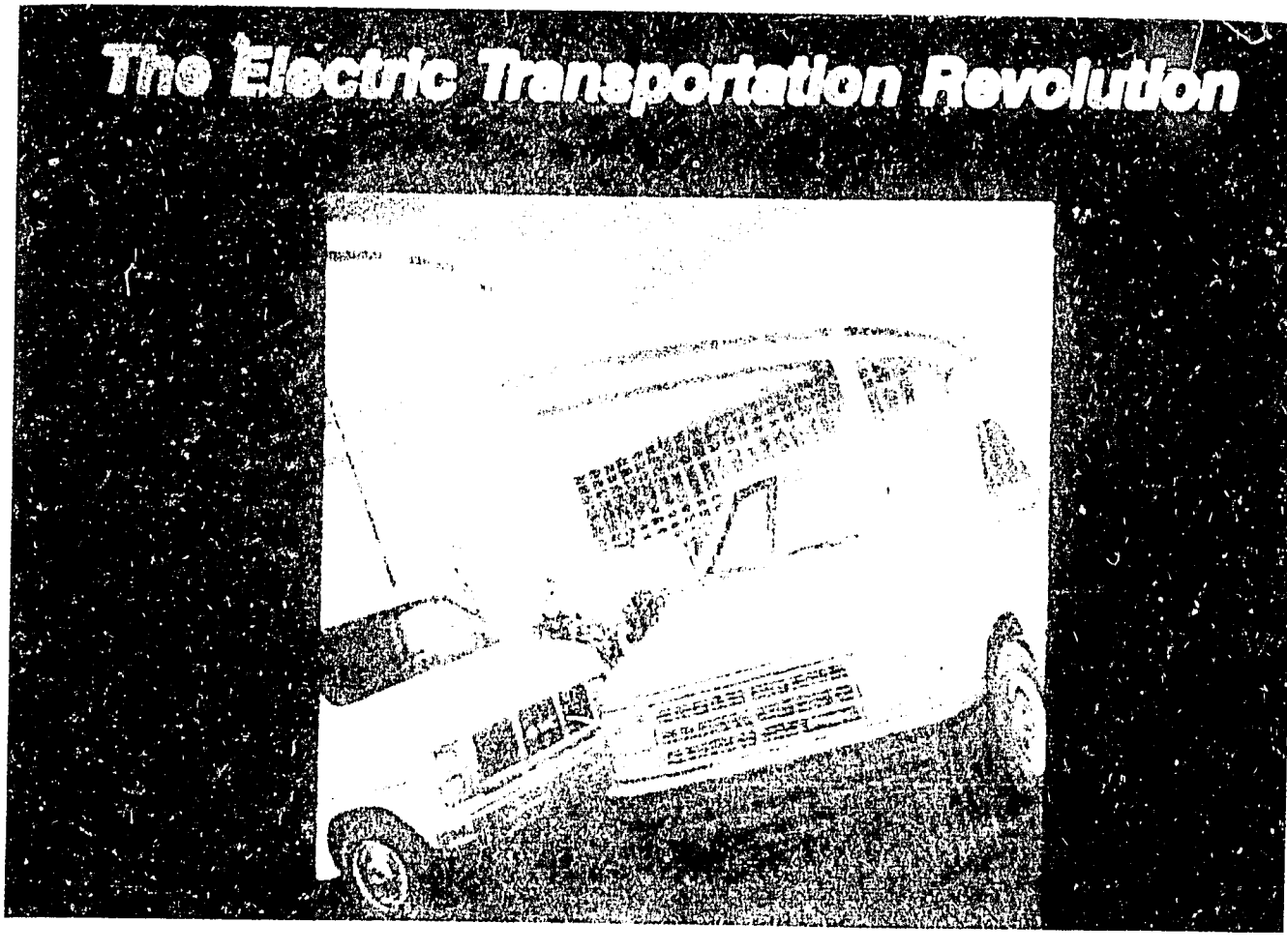
Shri B.D. Bose chaired the Session II on Technology for Electronic/Electric Vehicles (EVs). He recalled that seven years ago CII had organised a workshop at Calcutta in which one paper on EVs and Batteries for EVs were presented. Today a stage has come when we are having a workshop to discuss technology and policy issues concerning EVs. He remarked that California legislation had played a significant and leading role in promoting EVs and creating awareness on a global basis, as a result of which many countries in the world have now programmes for development and promotion of EVs. In this direction India has also taken a timely step.

Mr. Bose further said that the EVs are yet to become a commercially viable proposition. To achieve this many countries have initiated R&D projects for development of critical technologies required for EVs. The critical technologies for promoting EVs on large scale include Electronic Control, Motor and Battery. There are other problems associated with EVs such as initial high cost, limited range, high life cycle cost etc. Also operating and maintenance cost of EVs do not favourablly compare with fossil fuel vehicles. However, with the availability of high energy batteries and recent developments in electronic drive and motor technologies, drastic reduction in the operating and maintenance cost of EVs have been achieved in USA. This is yet to happen in India.

Mr. Bose stated that the movement for popularisation of EVs is gaining momentum. The Government is fully committed to the development and promotion of EVs in India. Some incentives are already being offered to EV operators. Mr. Bose stressed the need for participation of automotive industry, concerned institutions and Government agencies for obtaining fruitful results in this area. Mr. Bose opined that it is right time to discuss and look into all aspects of technologies required to make EVs popular in India.

Overview of Role of Electronic/Electric Vehicles (EV) in Transportation

Veronika Rabl
Electric Power Research Institute (EPRI)
and
Carl J. Hocevar
RCG/Hagler Bailly, Inc.



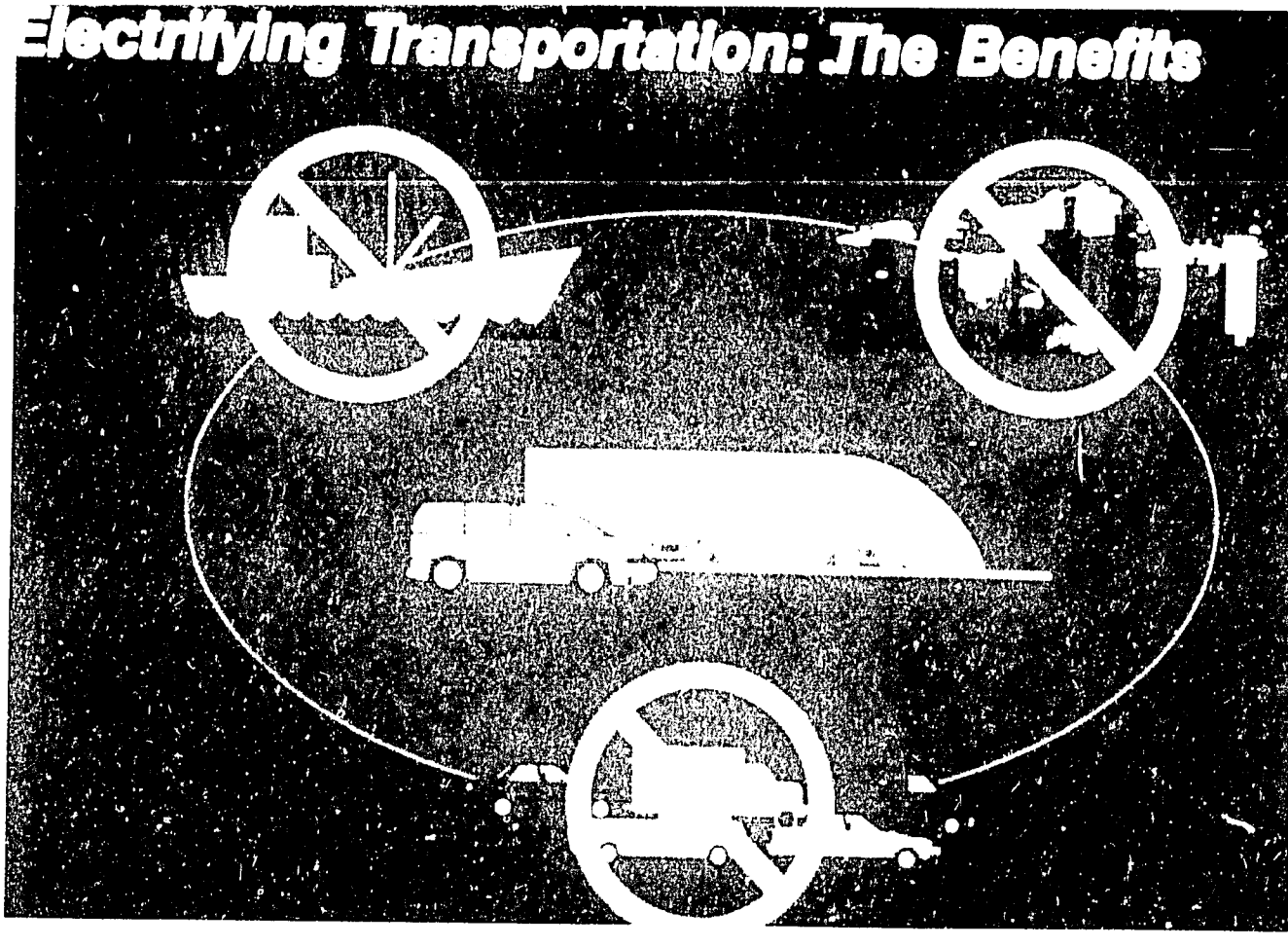
The Electric Transportation Revolution

Slide 1

April 1992
EPRI Transportation Program

The Decade for electric Vehicles

By the end of the 1990's, electric vehicles (EVs) will likely be a familiar transportation option in the United States - a goal achieved through the foresight and efforts of industry leaders and policy makers. Through the Electric Power Research Institute (EPRI), the electric utility industry has been a key player in the EV movement and will continue to participate in EV development. But as the automotive industry increases its commitment to EVs, the utility industry is shifting to a broader focus: building the EV fueling infrastructure and maximizing electricity use in the transportation sector.



Electrifying Transportation: The Benefits

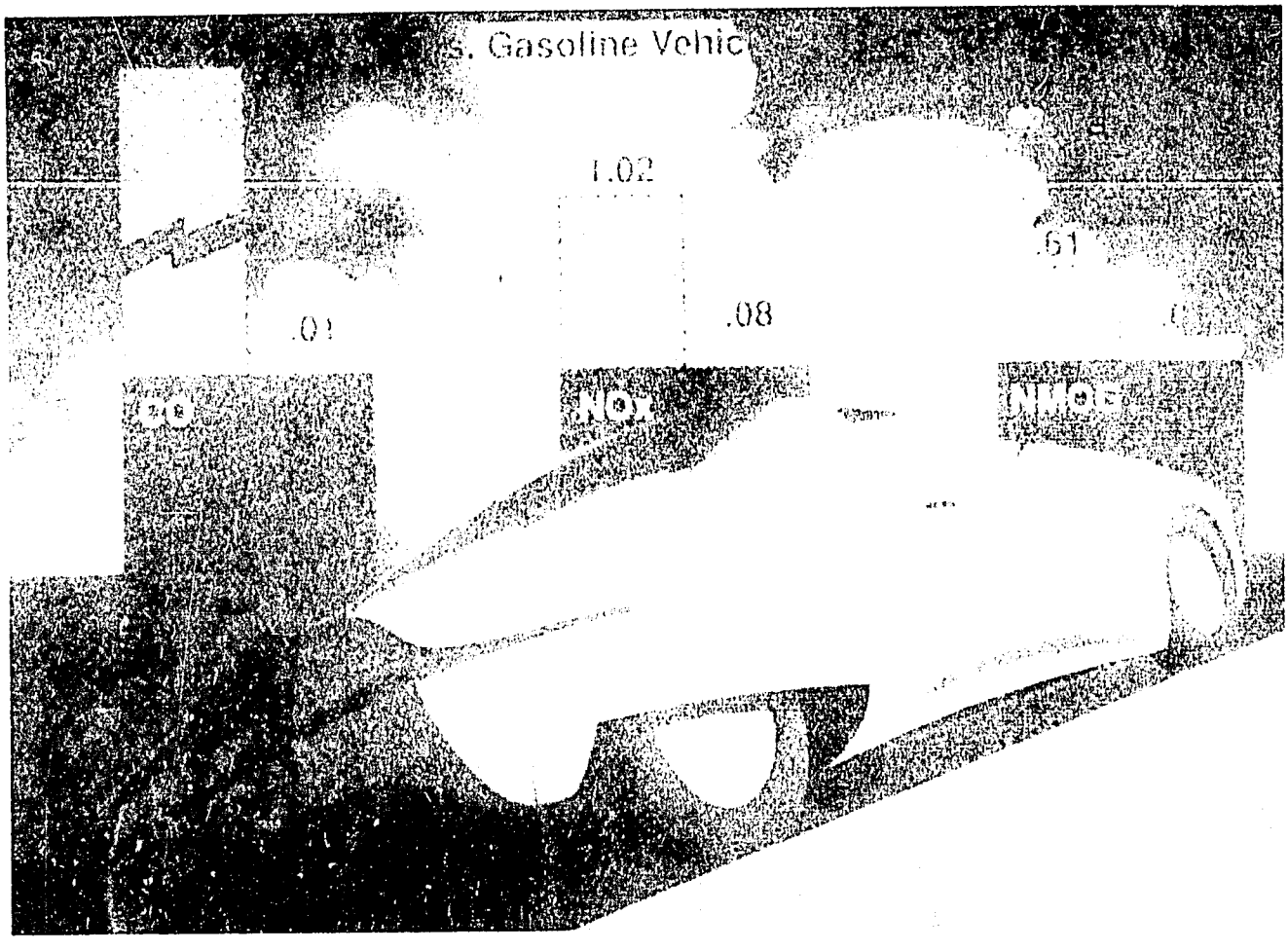
What are the benefits of electrfying the transportation sector? By displacing gasoline-and diesel-powered vehicles, clean EVs and electric urban transit and intercity rail can help:

- Improve local and regional air quality by decreasing emissions of nonmethane organic gases (NMOG) and nitrogen oxides (NOx), which combine to form smog; and carbon monoxide (CO).
- Decrease emissions of carbon dioxide (CO2), the principle gas linked with global warming
- Allow greater use of domestic fuels in transportation, as nearly all electricity is produced from domestic fuel and energy sources
- Increase the energy efficiency of the transportation sector

In addition, properly designed electric transportation systems help increase mobility and facilitate regional economic growth.

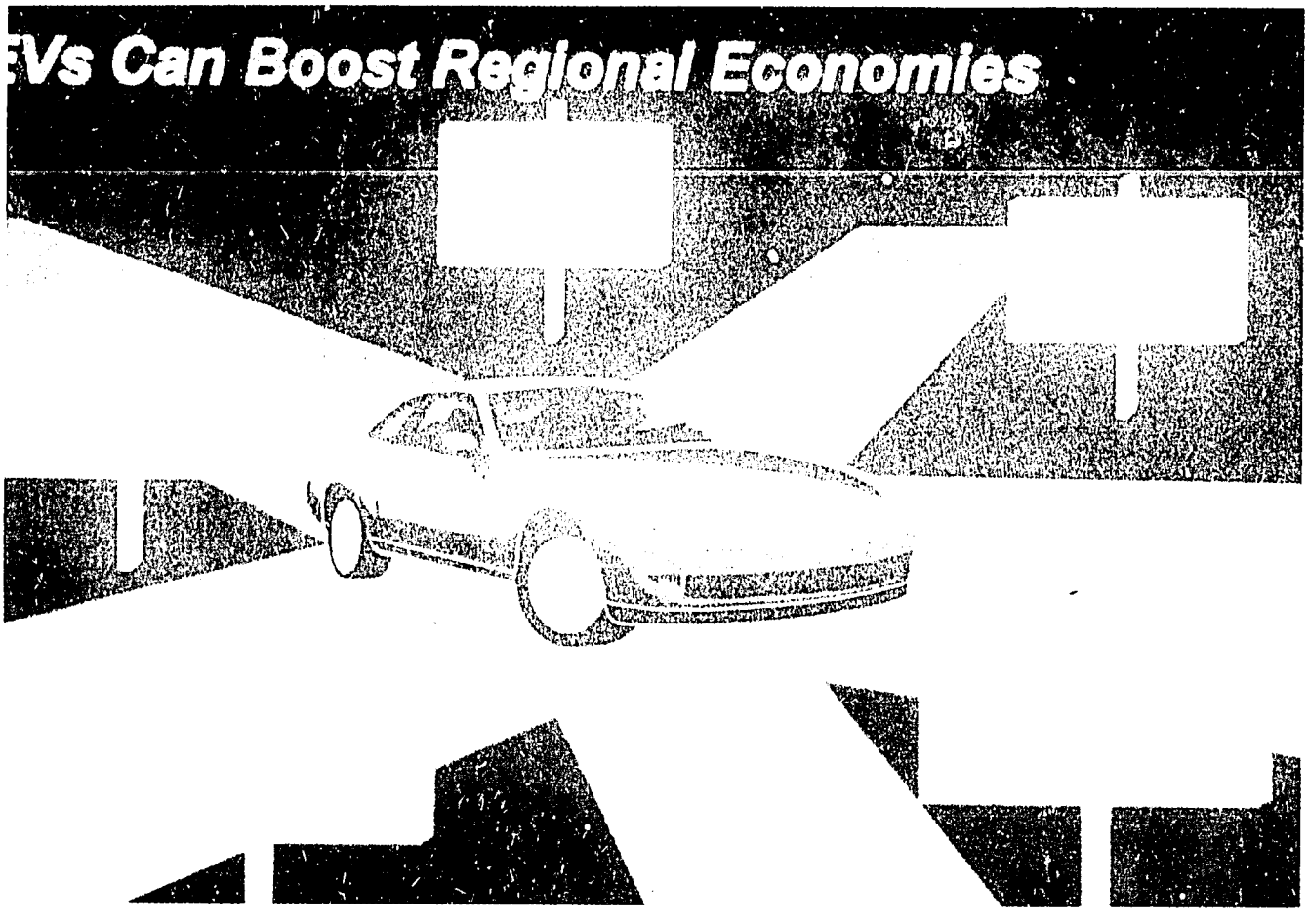
Slide 3

April 1992
EPRI Transportation Program



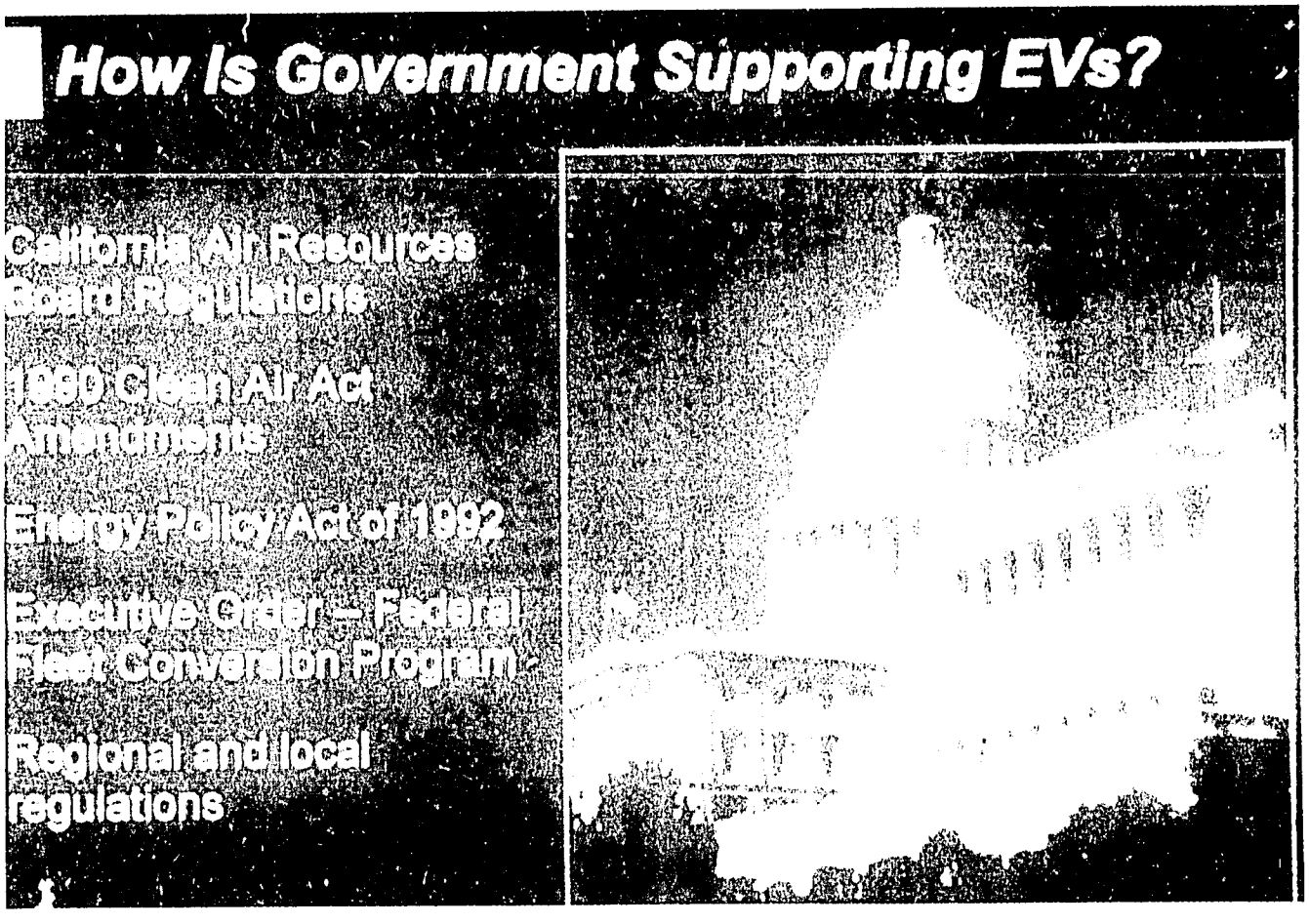
Coming Out Clean

Electric transportation also promises to help clean up skies over urban areas. Currently, emissions from conventional cars and trucks account for about 60% of the smog problem and more than 80% of all carbon monoxide emissions. An EPRI study estimated that in typical urban areas, substituting an EV for a gasoline-powered vehicle would reduce emissions of carbon monoxide by 99% nitrogen oxide by 92% and nonmethane organic gases by 98%. (These figures assume U.S. 1995 emission standards for conventional vehicles and the U.S. post-1995 power plant emissions standards for the generation mix of a typical urban area.) Substituting electric trains and buses for diesel-powered vehicles would remove cancer-causing particulates and soot from urban areas. To complete the picture, EPRI plans to study the air quality impacts of other electric transportation options this year.



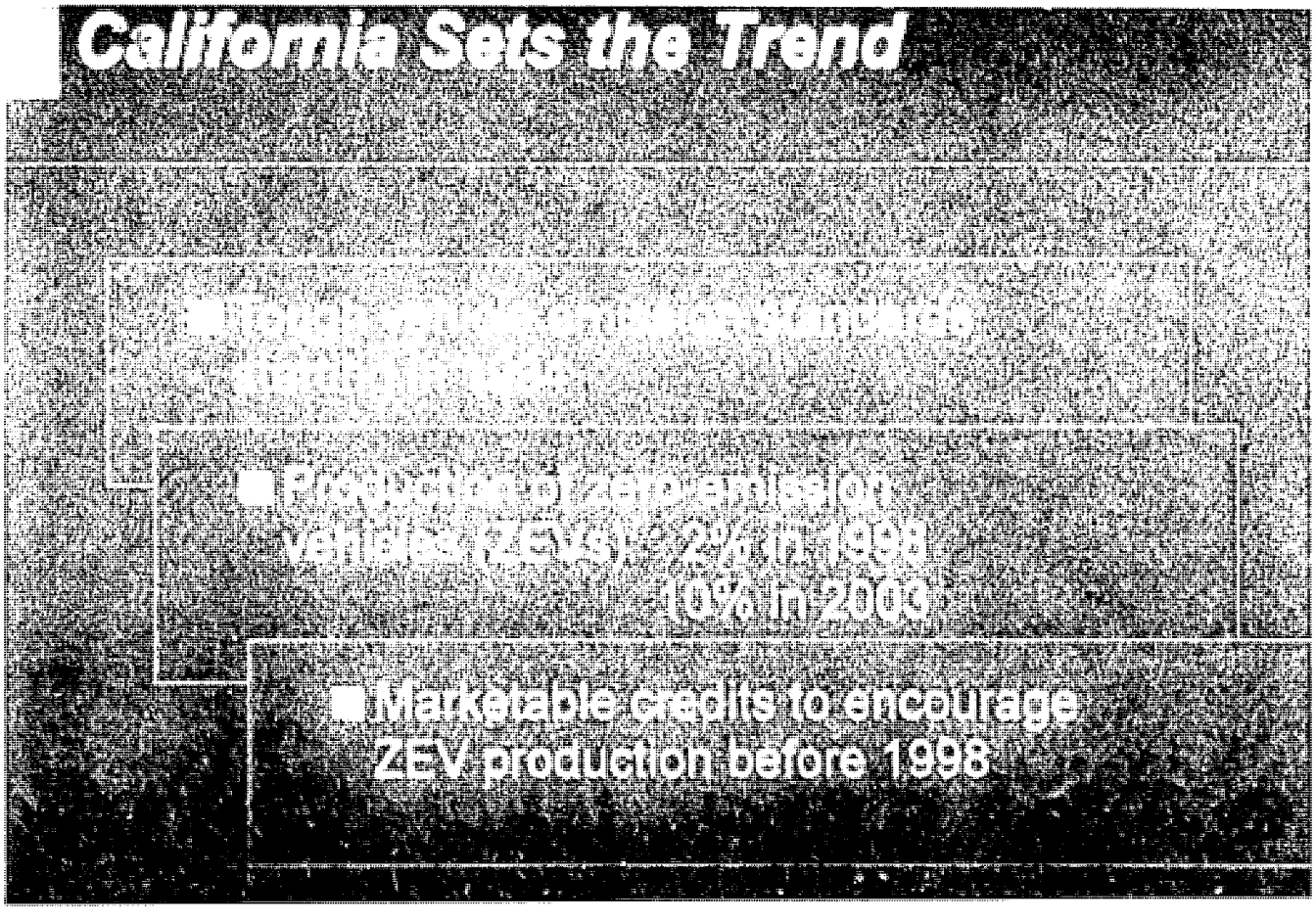
EVs can boost Regional Economies

The EV's potential to aid economic recovery - especially in high-tech industries affected by defense spending cuts - has generated active interest. For example, the Advanced Research Projects Agency (ARPA), the agency that disburses defense R&D funds, has awarded 525 million to six regional consortia from New York to Hawaii to demonstrate EV technology and infrastructure. Funding from energy security legislation is also specifically earmarked for projects cosponsored by aerospace and defense contractors looking for markets for their expertise.



How is Government Supporting EVs?

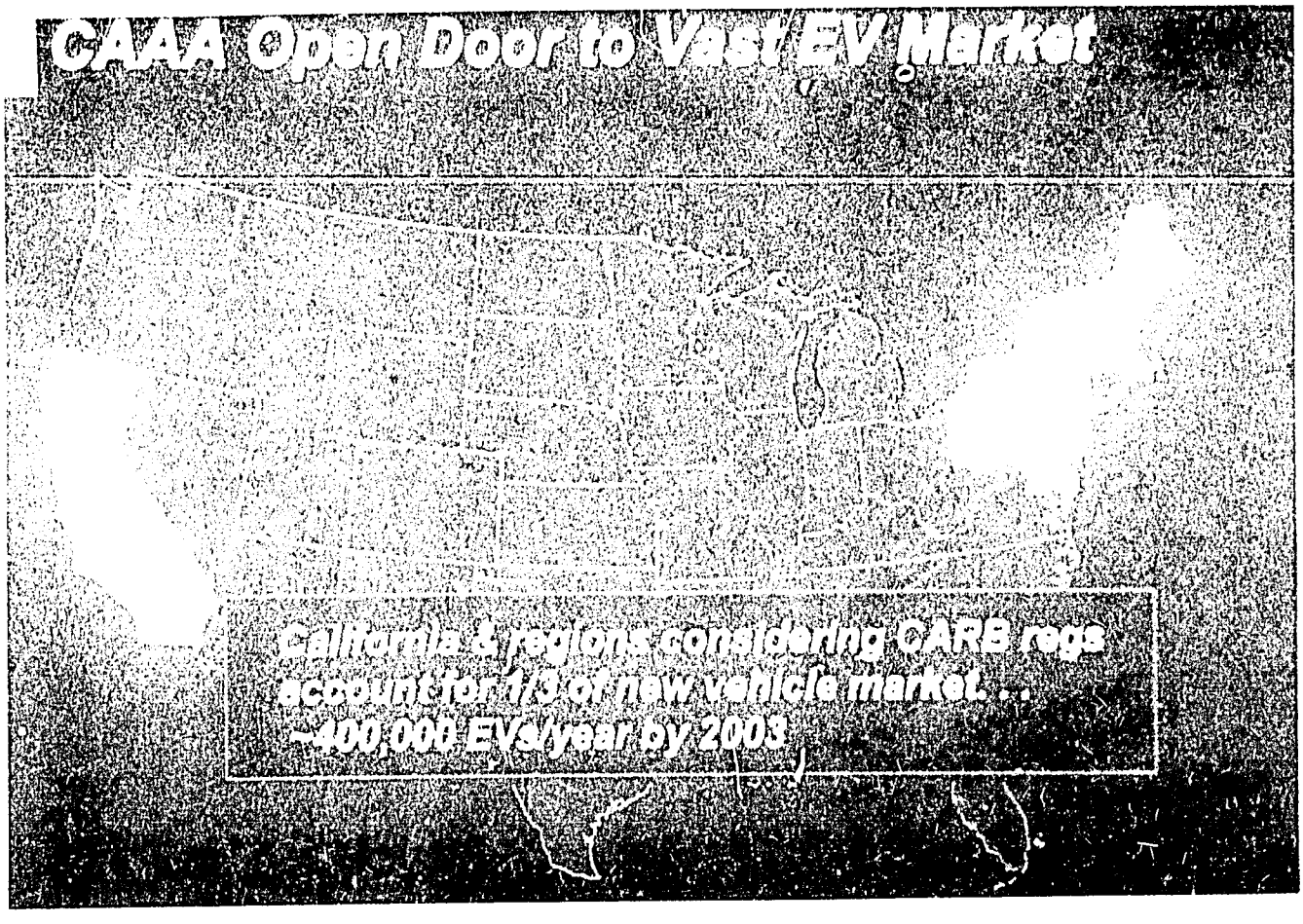
Federal, state, and local policy makers have gotten the message about EVs and are responding vigorously by enacting laws that require the use of alternative - fuel vehicles - and sometimes single out EVs for special treatment.



California sets the Trend

The single biggest push for EVs has come from the state of California. To address the state's severe air quality problems, the California Air Resources Board passed stringent clean-vehicle regulations. These rules set the strictest tailpipe emissions standards in the world and require automakers to begin producing zero-emission vehicles (ZEVs) for sale in the state. Starting in 1998, 2% of all new passenger cars and light-duty trucks offered for sale - or more than 24,000 vehicles - must have zero emissions, a qualification only EVs meet at the present time.

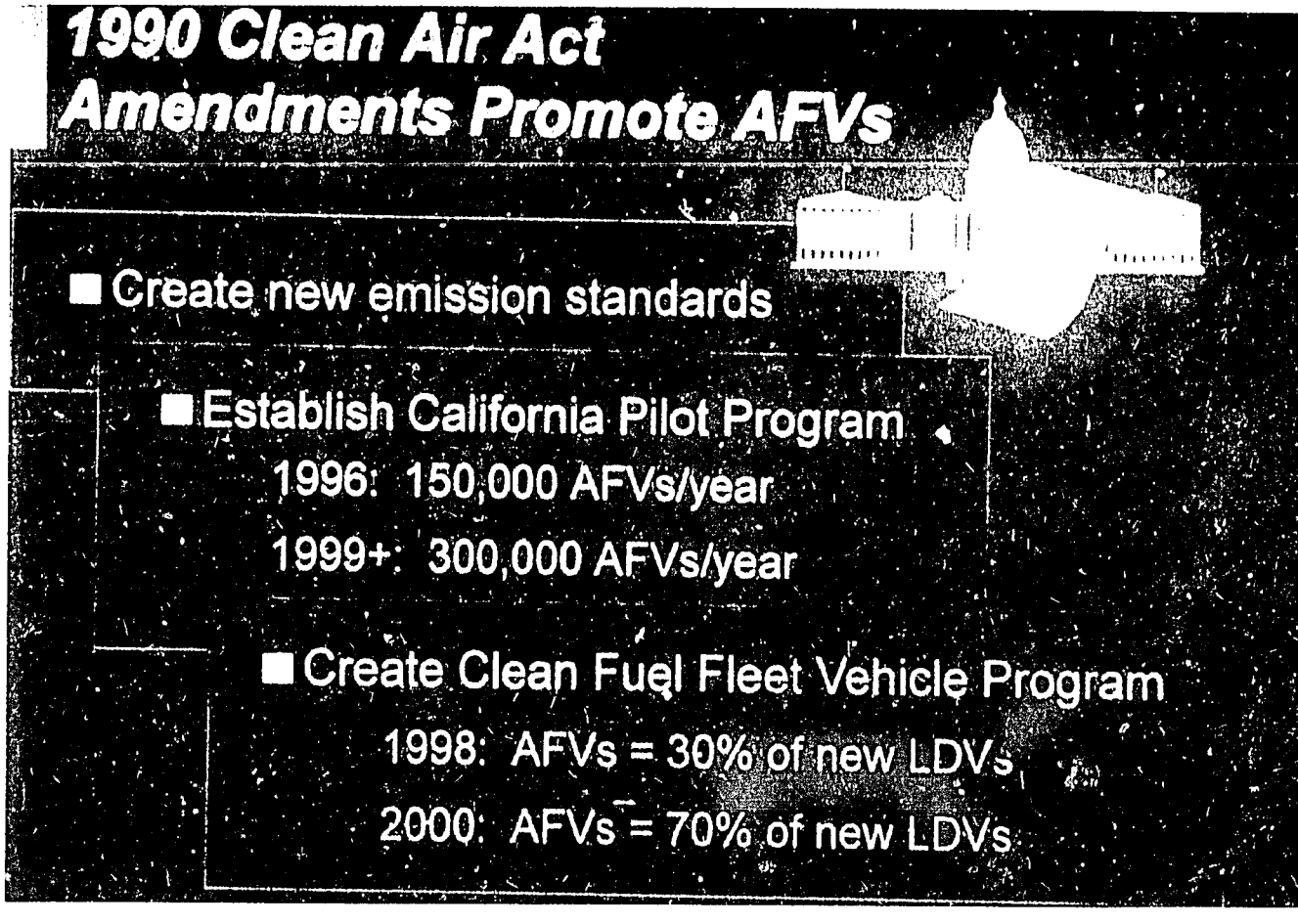
By 2003, 10% - or about 122,000 - of new vehicles produced must by ZEVs. That's as many vehicles sold in the United States by BMW and Mercedes put together- and more vehicles that are sold in a year in the states of Connecticut, Colorado, or Washington.



CAAA Open Door to Vast EV Market

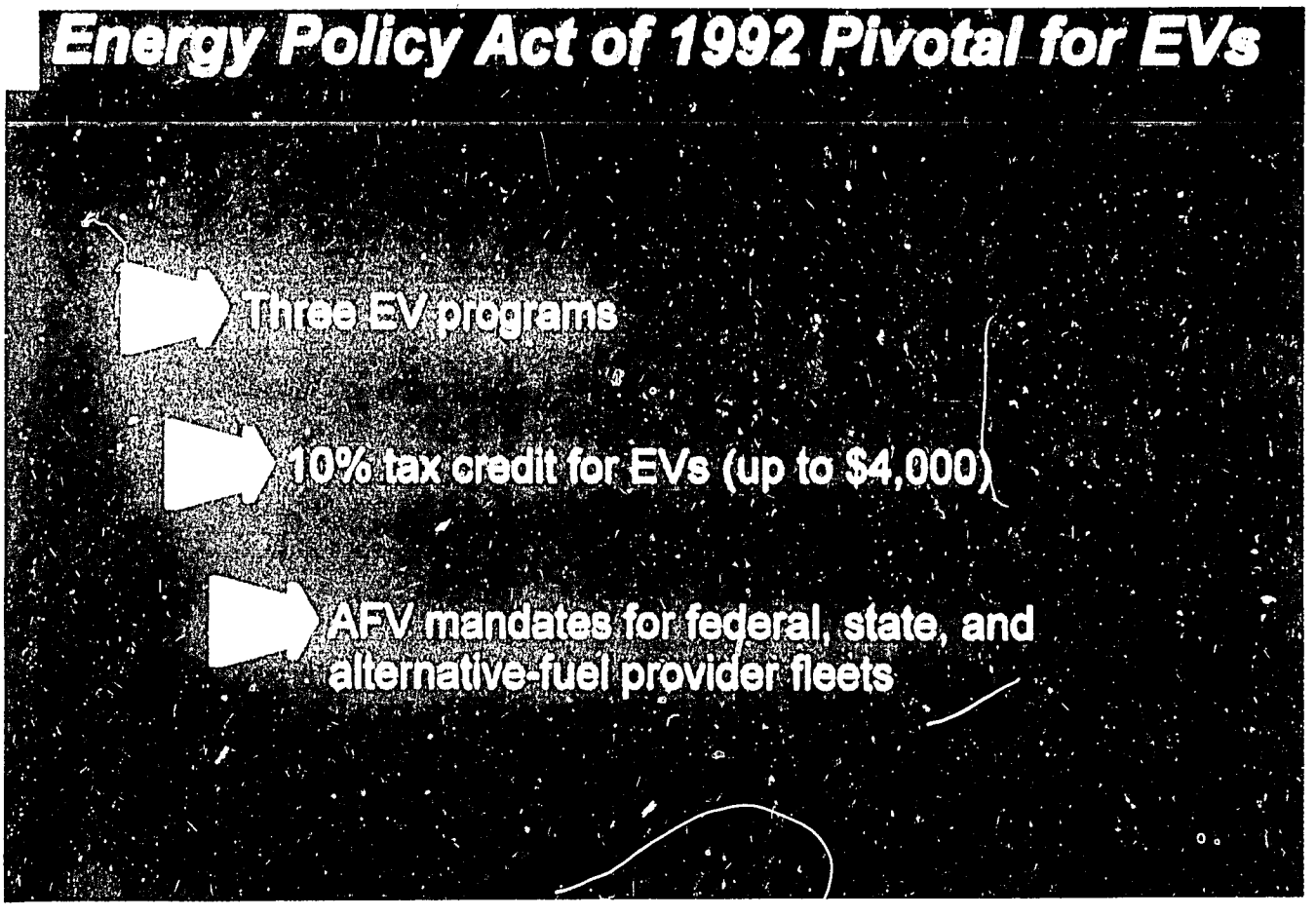
Although the CAAA don't specifically require the use of EVs, one CAAA provision opens the door to an EV sweep. This provision allows states to adopt either the new federal emission standards or the more stringent California emission standards. Several northeastern states-Maine, Massachusetts, Maryland, New Jersey, and New York-have adopted the California rules, including the zero-emission requirement, and other states are considering such a move. Successful implementation of zero-emission requirement in all these states would create an impressive market for EVs: about 400,000 EVs per year by 2003. That's roughly the number of vehicles Honda sells in the United States in a year.

States are also encouraging EV use in other ways. Some, including Louisiana, Pennsylvania, and Utah, are granting tax credits for EV purchases. Arizona provides a discount on the annual license tax rates for EVs, and Pennsylvania waives registration fees for EVs. Many states are also planning to set up EV demonstrations, some of which will be partially funded by the federal initiatives described earlier.



1990 Clean Air Act Amendments Promote AFVs

The 1990 Clean Air Act Amendments (CAAA) established strict emission standards nationwide (through not as strict as California's), and created two programs that promote the use of alternative-fuel vehicles (AFVs), including EVs: a pilot program in California, and a Clean Fuel Fleet Vehicle Program in the most polluted cities nationwide. In fleets targeted by this program. AFVs must make up 30% of new light-duty vehicles-cars and some vans and pickup trucks-in 1998, and 70% of new light-duty vehicles in 2000. Electric vehicles qualify as AFVs, as do vehicles running on natural gas, propane, methanol, and ethanol.

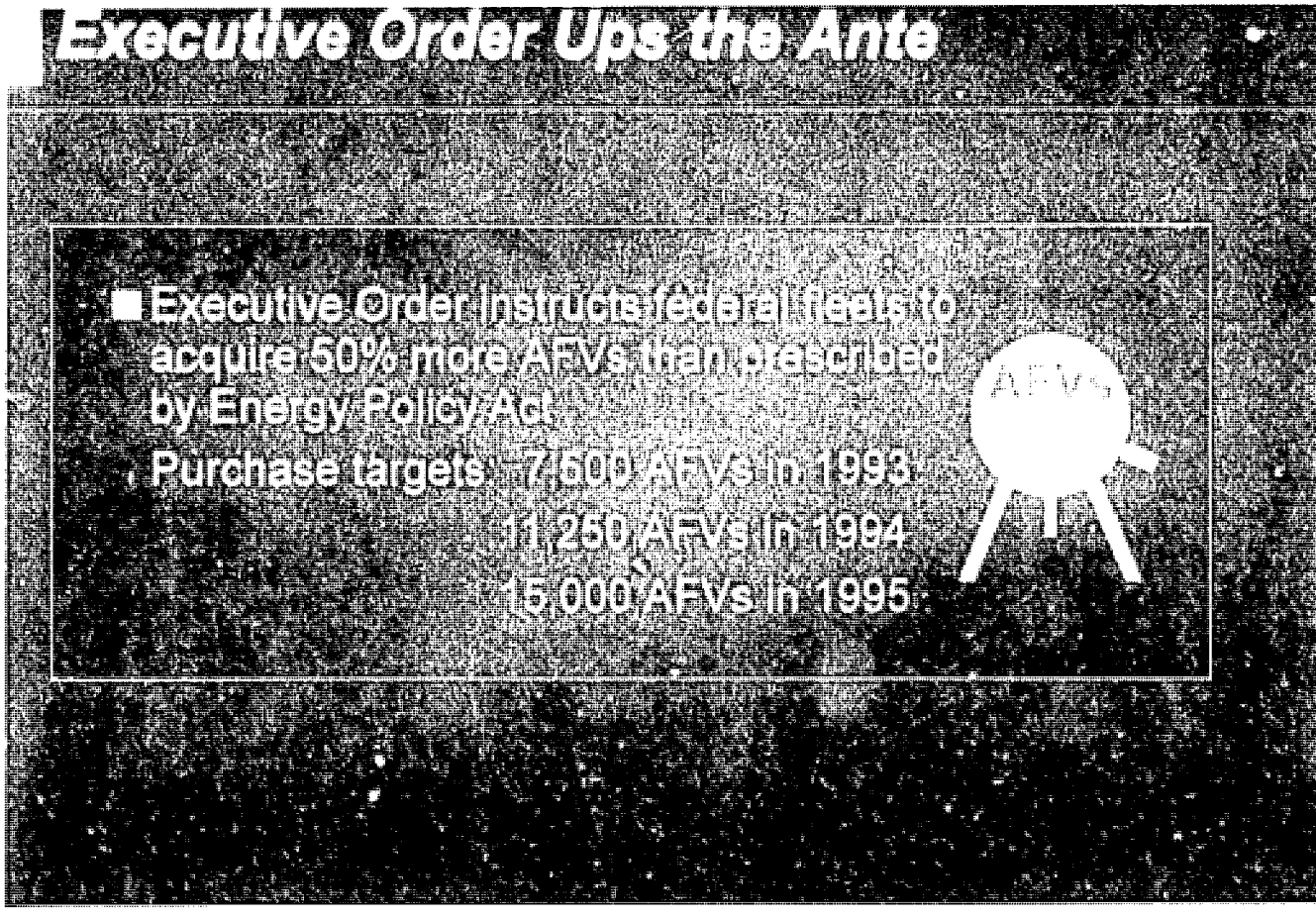


Energy Policy Act of 1992 Pivotal for EVs

Given the EV's potential to dramatically reduce petroleum use in transportation it's no wonder that key elements of the national Energy Policy Act of 1992 are intended to spur EV development and purchases. For starters, the bill creates an EV research program, an Ev demonstration program, and a program to demonstrate the Ev infrastructure. And to encourage consumers, it provides EV buyers a tax credit equal to 10% of the EV purchase price, or up to $4000.

The bill also requires many different types of fleets to begin buying AFVs. Primary targets are fleets owned by alternative-fuel providers, including electric utilities, and some federal, state, municipal, and private fleets located in urban areas.

Initially, the heaviest charge falls on alternative-fuel providers, who must ensure that 30% of the new vehicles they purchase in 1996 are AFVs. That percentage increases incrementally to 90% in 1999 and beyond. Electricity providers whose EVs to meet the requirements will not have to comply until December 31, 1997-a delay intended to buy time until EVs become more readily available.



Executive Order ups the Ante

To encourage and accelerate use of AFVs in fleets, President Clinton signed an executive order that requires federal fleets to buy 50% more AFVs than mandated by the Energy Policy Act for the years 1993 to 1995. to help implement the order, the President has established a Federal Fleet Conversion Task Force. This interagency. interindustry group is charged with developing a plan to help fleets meet this acclerated schedule.

Slide 12

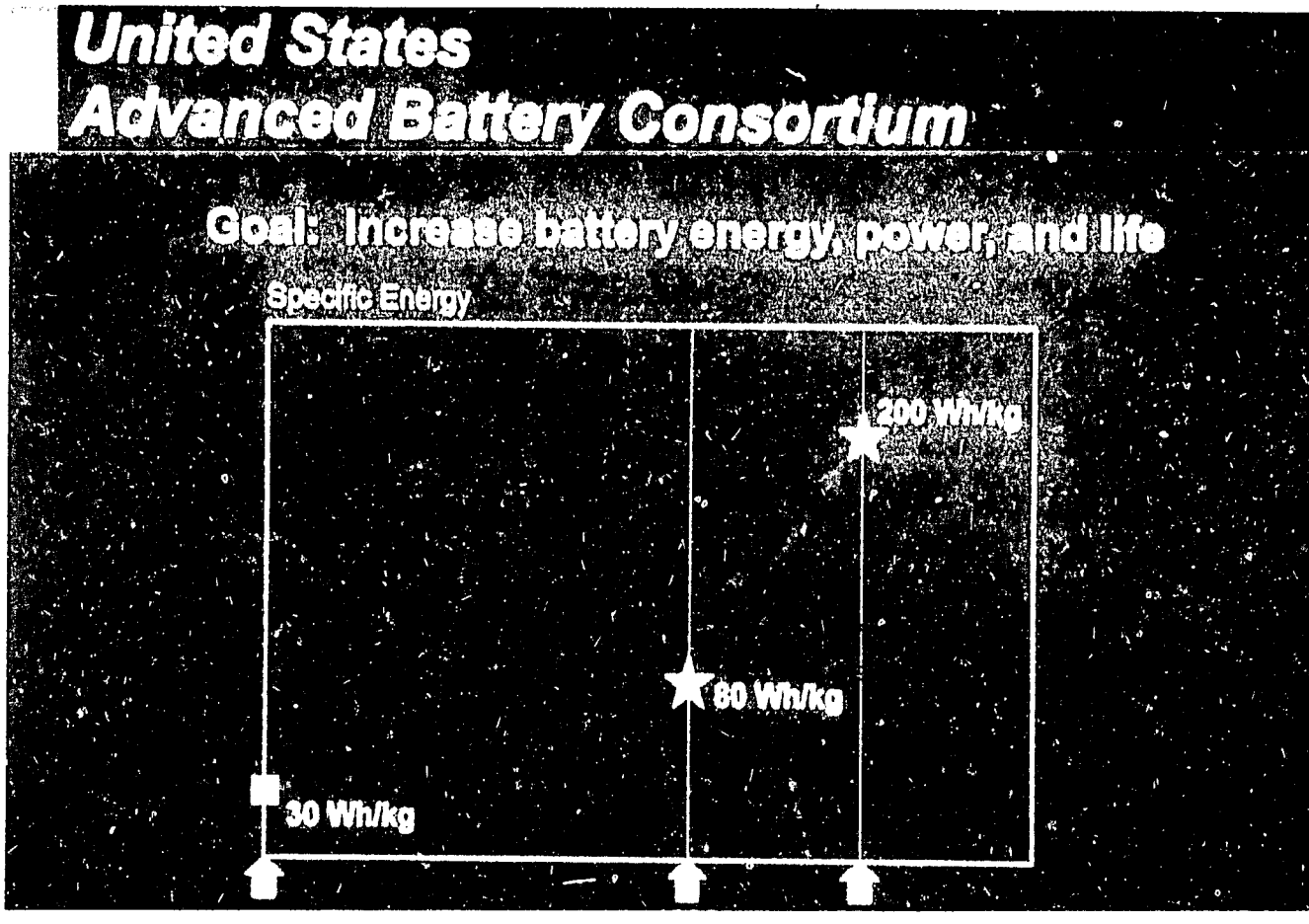
The United States Advanced Battery Consortium

- Sodium (Sulfur)
- Lithium Polymer
- Nickel Metal Hydride
- Li(Al)-FeS

Participants

- Big three automakers
- Utilities/EPRI
- Battery industry
- U.S. Government (DOE)

Slide 13



United States Advanced Battery Consortium

The major EV battery research today is channeled through the United States Advanced Battery Consortium (USABC). A research consortium comprising the U.S. Big Three automakers, EPRI and participating utilities, and the U.S. Department of Energy (DOE), USABC is developing batteries to meet 1998 EV requirements and to eventually provide EV performance comparable to that of conventional cars.

USABC: Primary Criteria for Batteries

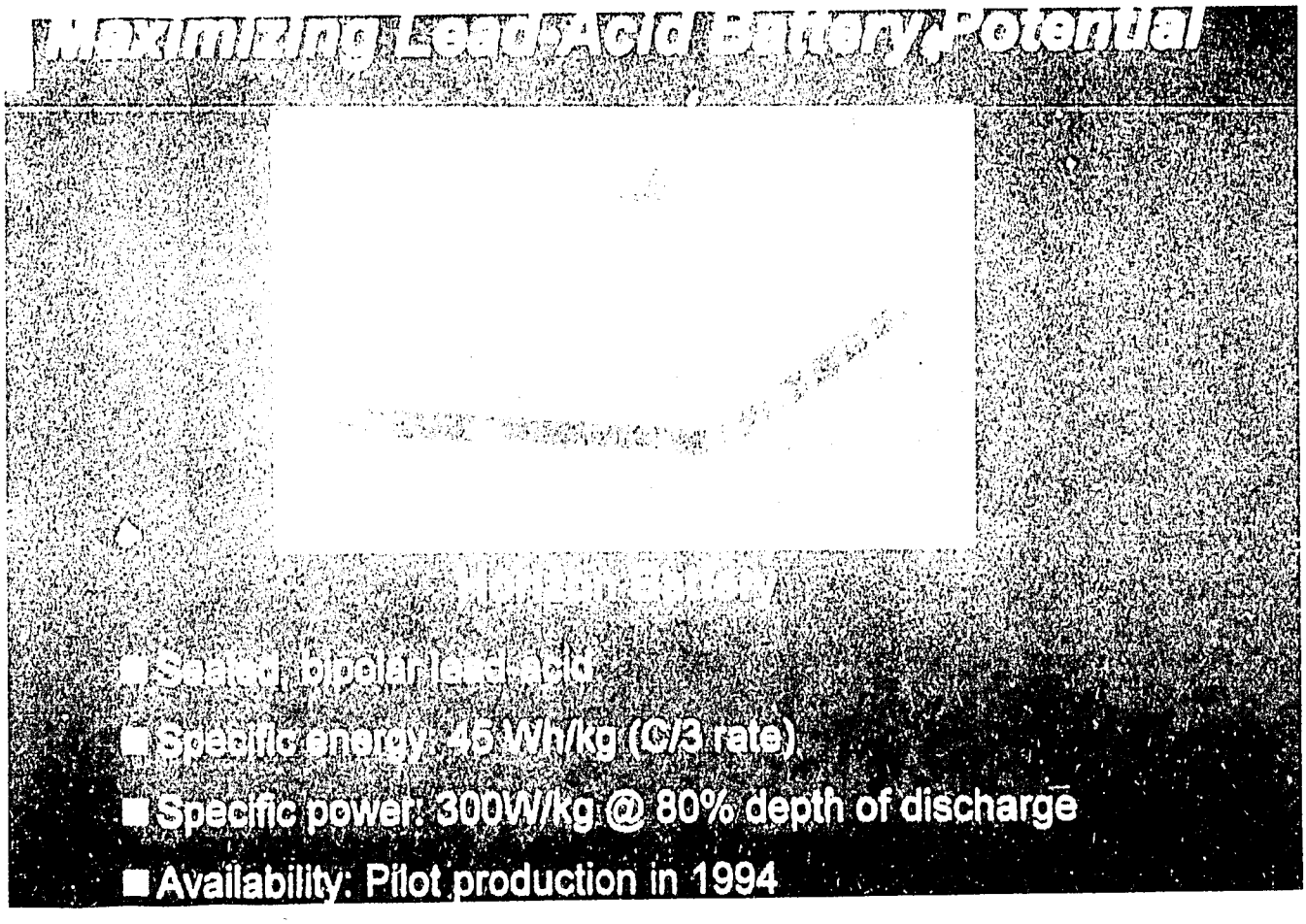
	Mid-Term	Long-Term
Specific Energy Wh/kg (C/3 discharge rate)	80* (*100 desired)	200
Energy Density Wh/L (C/3 discharge rate)	135	300
Specific Power W/kg (@80% DoD)	150* (*200 desired)	400
Power Density W/L	250	600
Life (years)	5	10
Cycle Life (cycles/80% DoD)	600	1000
Ultimate Price ($/kWh)	<$150	<$100
Recharge Time	<6 hours	3 to 6 hours
Maintenance	Completely Maintence Free for Customer	

EPR

[illegible]	165*	[illegible]	N/A	N/A	N/A
[illegible] Polymer	150*	120*	N/A	N/A	N/A

*Projection based on cell performance
N/A = Data not available

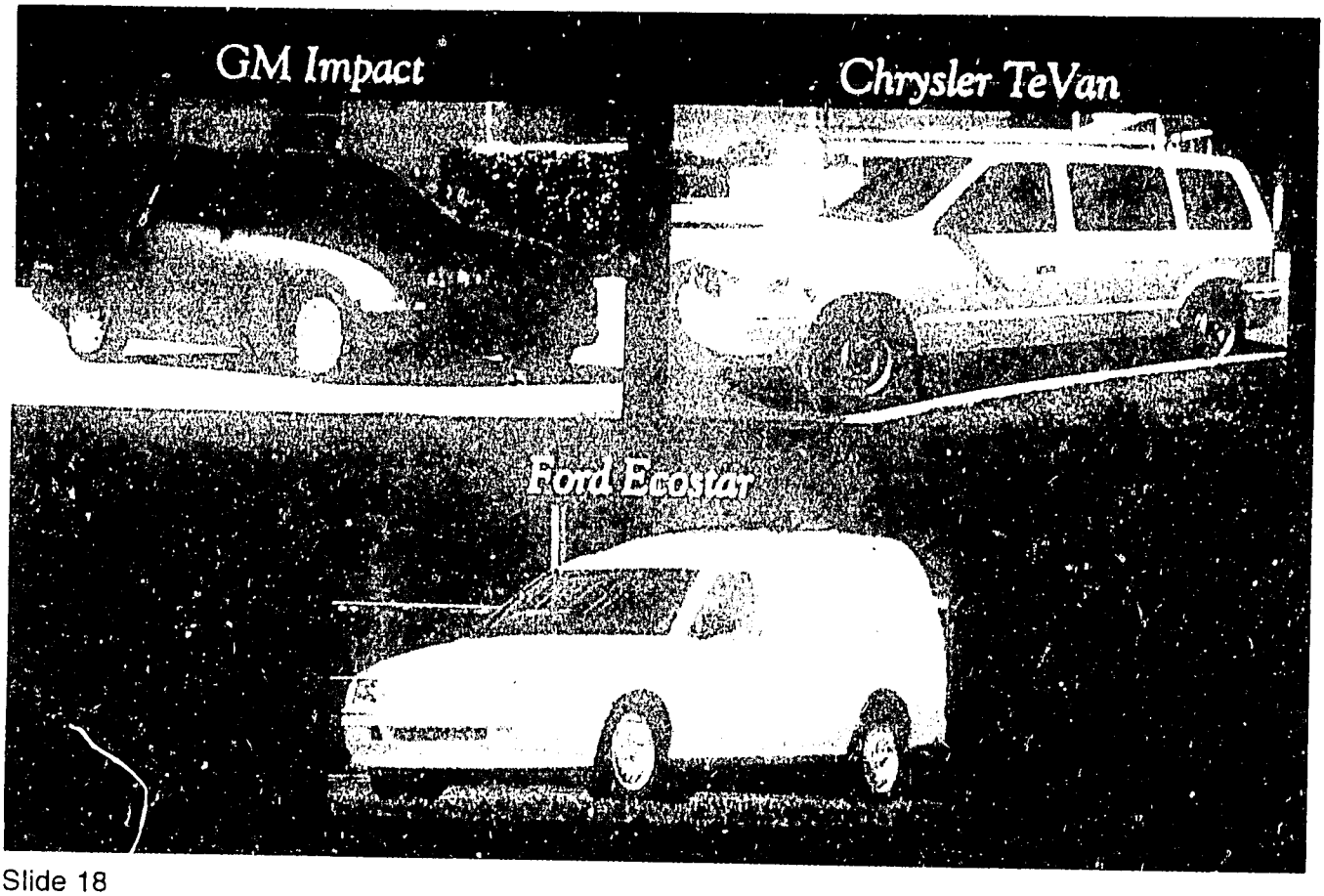
Advances in battery technology are occuring rapidly, and some of the data in this slide is outdated. Battery developers should be contacted for state-of-the-art information.



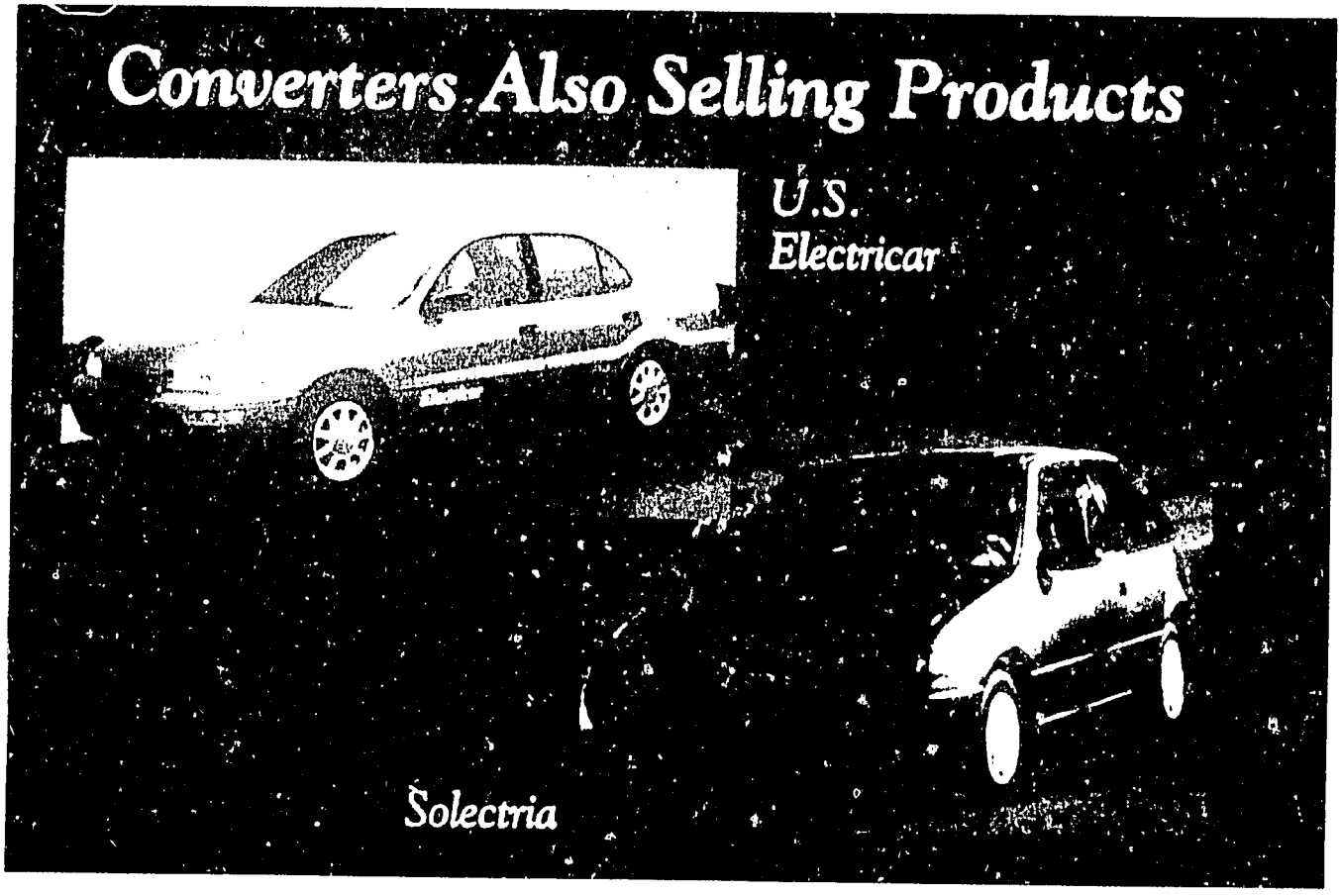
Maximizing Lead-Acid Battery Potential

While awaiting results of USABC work, the utility industry is teaming up behind high-potential near-term systems. Encouraged by favorable evaluation results for the Electrosource Horizon battery, for example, EPRI initiated a utility-sponsored project to fund development and pilot production of this advanced lead-acid system. To date, the Horizon battery has achieved a specific energy of 45 Wh/kg when discharged at a constant rate over three hours (C3) - a significant advance over traditional lead-acid batteries, which average about 30 Wh/kg.

EPRI is also monitoring other promising battery systems for possible joint development.



Slide 18



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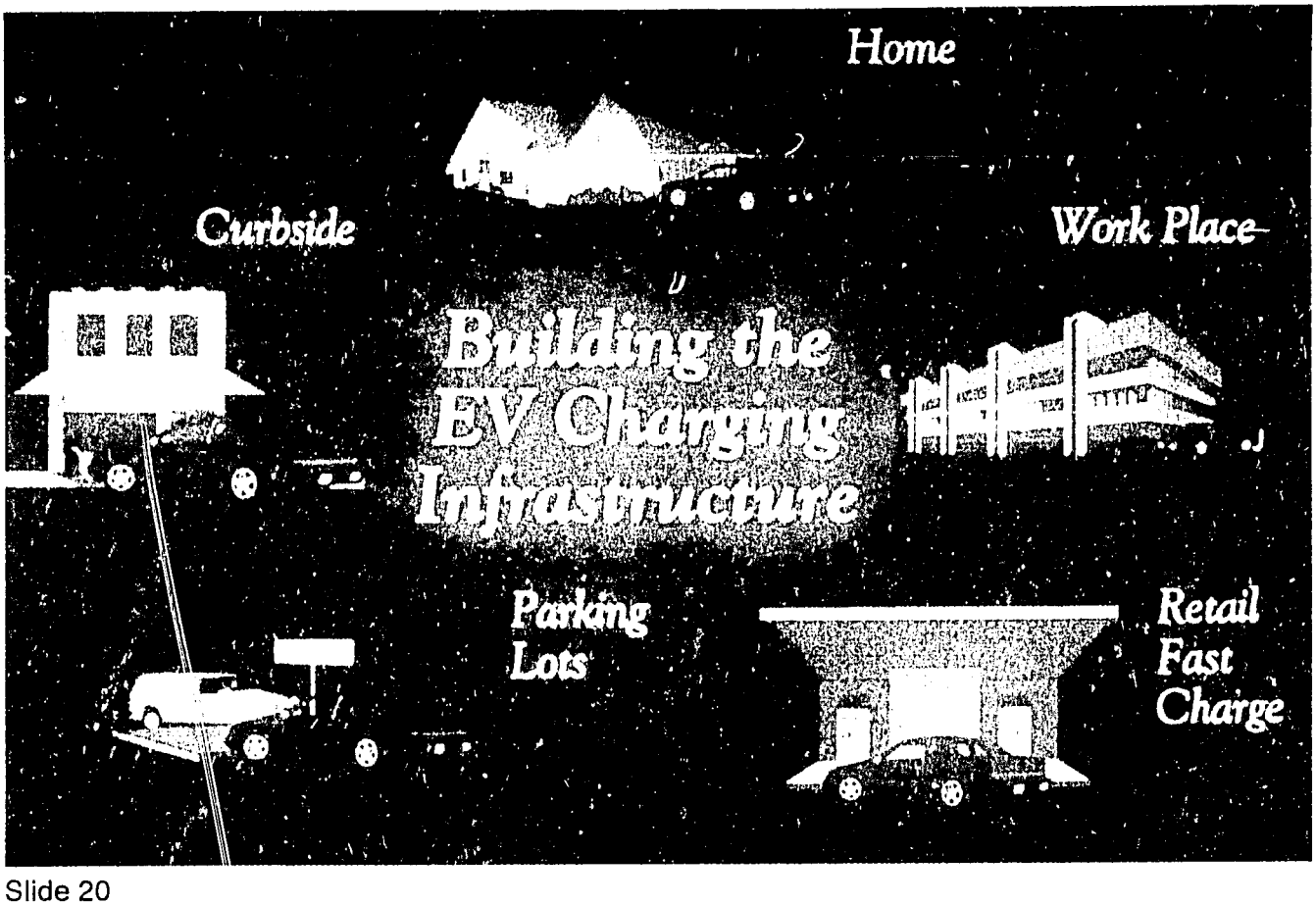

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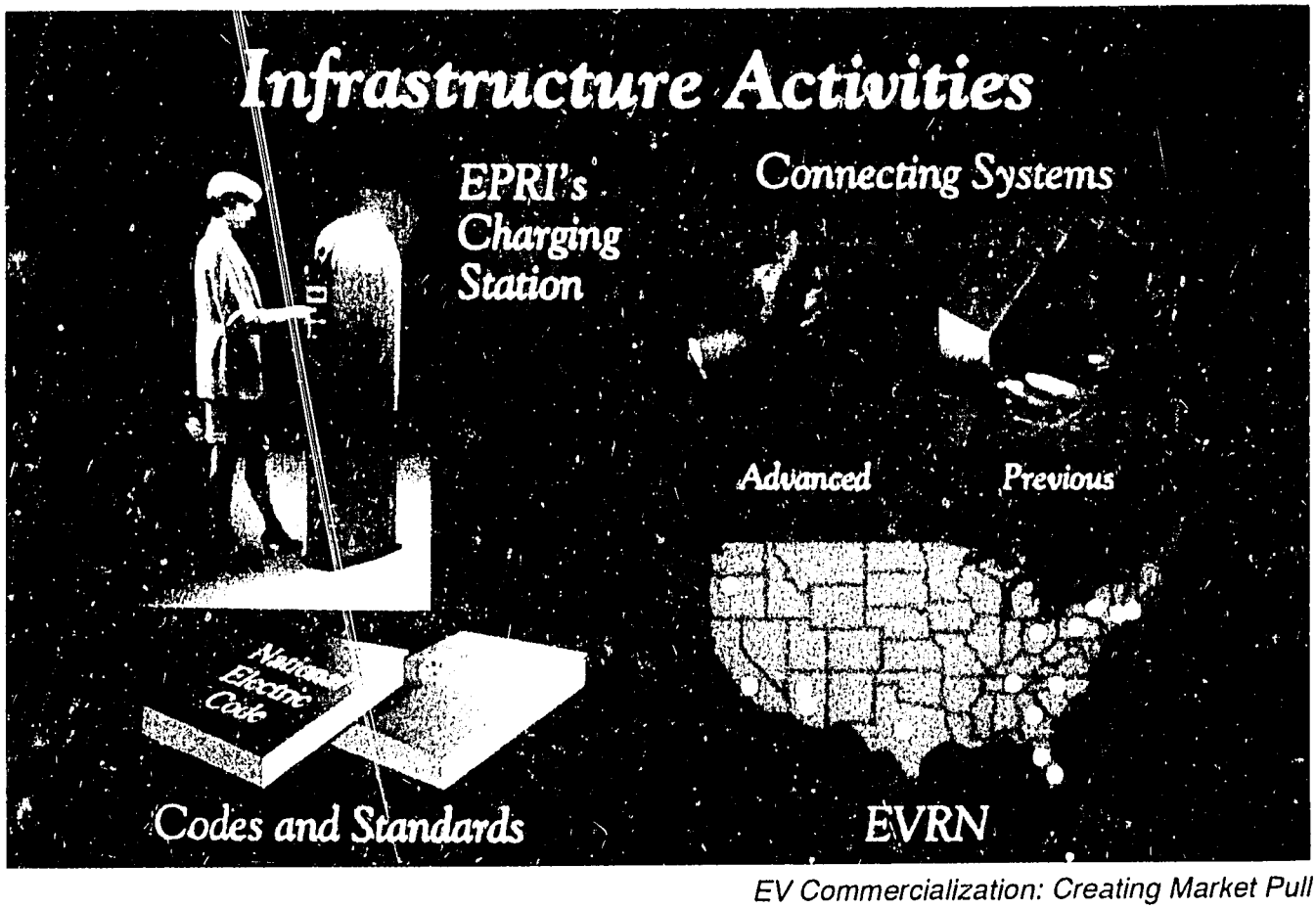

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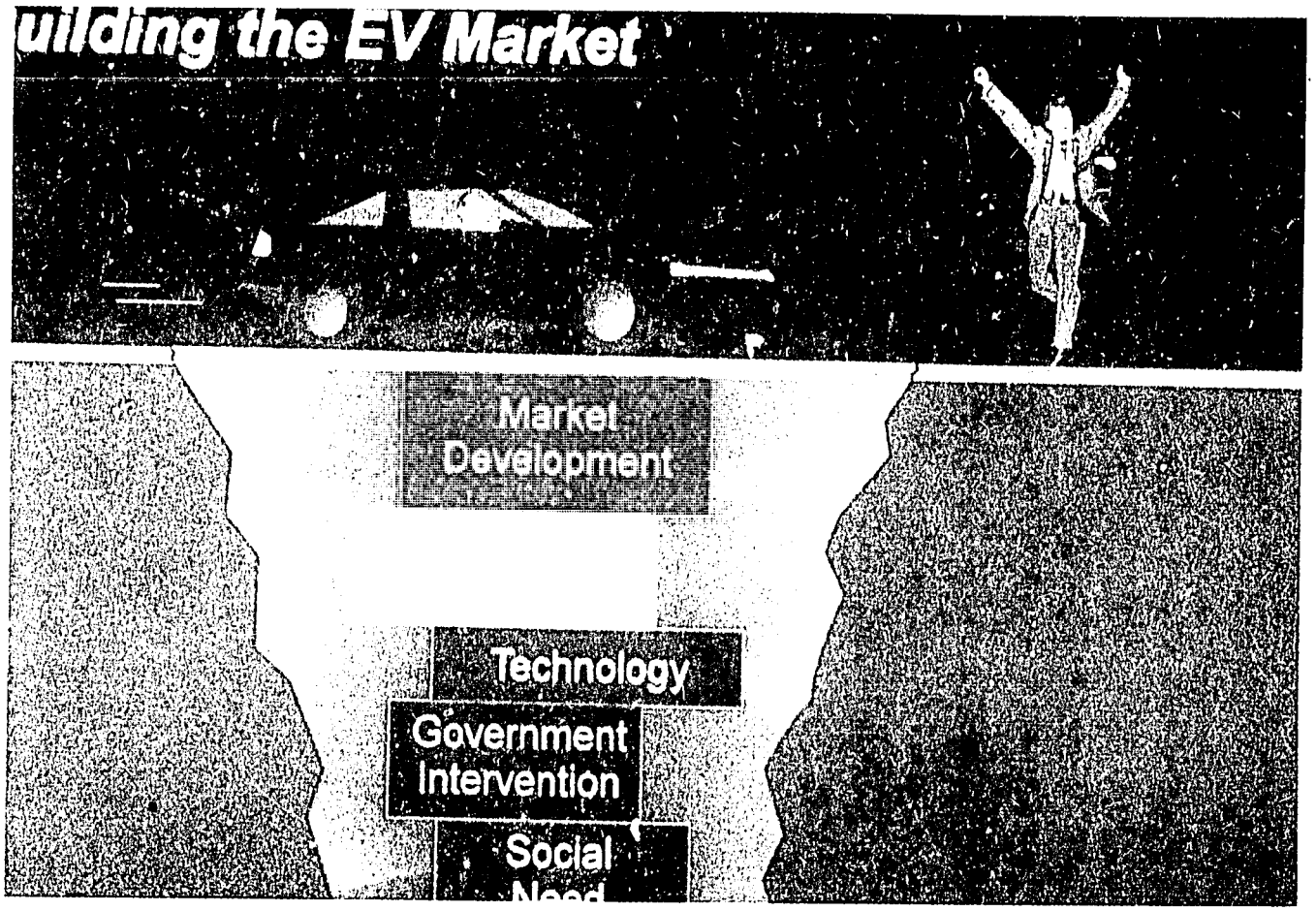


Building the EV Market

The basic elements necessary to create market pull for EVs is coming into place. The social need has been established. Legislation to help push product and market development has been enacted and more initiatives are on the way. EV technology, infrastructure, and market activities are more improved, more convenient products closer to a better informed public.

The biggest test-developing a product that is an attractive alternative to conventional vehicles-still lies ahead. But with this foundation in place, the EV commercialization challenge can be met.

Battery Development for Electric Vehicles

Mr. S. K. Mittal
Executive Vice-President (R&D)
Chloride Industries Limited
Calcutta

1. Present Scenario

Considering the present growth rate of the vehicle population and the prevailing emission standards in the country, the extent of air pollution especially in the metropolitan cities is likely to reach serious, if not alarming levels. Therefore, there is an urgent need to improve the emission standards as well as explore possibilities of introducing zero emission vehicles such as those powered by batteries. The latest World Resource Institute (WRI) report has been quite unequivocal in presenting its findings that the only practical means of introducing zero emission vehicles is through the electric vehicles, i.e. powered by batteries such as lead-acid, Ni-Cad etc.

Growing awareness of the seriousness of the pollution problems has resulted in the creation of several legislations in different regions of the world aimed at progressive introduction of low/ zero emission vehicles. California's legislation for example, mandates 2% of automobile manufacturers sale to meet zero emission standards by the year 1998, and 10% by 2003. The most likely approach is single or dual battery system to power such vehicles, but no technology is currently available to meet the needs satisfactorily.

As a matter of fact, mandated electric vehicle sales in California has been a subject of great controversy. Whereas California Air Resources Board (CARB) have decided to maintain the state's stringent emission standards, keeping in place 2% electric vehicle mandate, obviously has a major impact on the vehicle market in California. In specific terms, 7 major auto makers, namely General Motors, Chrysler, Ford, Toyota, Honda, Nissan and Mazda must each produce between 1000 - 7000 electric vehicles in 1998 for sale in California. Notwithstanding the popular opinion in California in favour of maintaining the electric vehicle sales mandate, the auto makers are trying for the change in legislation. In their opinion, the technology is not ready to commercialise electric vehicles. Infact, Japan and US auto makers equally share the view that the electric vehicle mandate should be removed or delayed.

2. Electric Vehicle Commercialisation - Limiting Factors

According to the Executive Vice President of Corporate Relations at Ford, "Technologically the critical path is the battery. And we must have a battery break-through to have a consumer-acceptable electric vehicles".

A Toyota's Technical Centre executive sums up their position as follows, "Toyota believes that the only viable battery technology for 1998 is lead-acid. Lead-acid battery range and performance will not satisfy customers. Until the electric vehicle range is significantly increased, electric vehicles will not be viable".

3. Indian Scenarion - Pollution by Vehicles

In view of the complexity of the problem, it will be worthwhile taking a close look at some of the recent reports on the pollutants emitted by vehicles to identify the areas requiring immediate attention. The following slide shows the annual fuel consumption by each category of vehicle in the year 1990:

Slide # 1

Fuel Consumption of different Vehicle Type - 1990

In million tonnes

Vehicle Type	Fuel Consumption
Diesel Vehicles	13.32 (Diesel)
Cars	1.52 (Petrol)
Motor Cycles/ Scooters/ Three-Wheelers	1.83 (Petrol)
Mopeds	0.45 (Petrol)

However, the emission characteristics of different vehicle types are widely different. Whereas the petrol vehicles contribute overwhelmingly to carbon-mono-oxide and hydrocarbon pollutants, NOx emissions are primarily contributed by diesel vehicles. An analysis done on the exhaust emission from different types of vehicles is shown in the next slide.

Slide # 2

Emission Characteristics of different Vehicle Types

In gm/litre of fuel consumed

Vehicle Type	CO	HC	NOx
Diesel Vehicles	19	8	37
Cars	240	31	16
Motor Cycles/ Scooters	257	161	1.8
Mopeds	304	215	1.8

Within the range of petrol vehicles, mopeds, scooters, motorcycles and 3-wheelers make a major contribution to hydrocarbon (74%) and carbon-mono-oxide (51%) emissions. this is due to the fact that in small 2-stroke engines, 15 - 40% of the fuel supplied to the engine is exhausted without participating in the combustion process. At present, bulk of the 2/3 wheelers are powered by 2-stroke petrol engines. Furthermore, the scope of improvement in the emission standard of 2-stroke petrol engines. 2-stroke engines is relatively small as compared to the 4-stroke engines.

Slide # 3

Pollutants Emited by different types of Petrol Vehicles - 1990

% contribution

Vehicle Type	CO	HC
Two wheelers	51.0	74
Cars	30.7	9

It is well known that the emission standards in the advanced countries are much higher and are improving progressively. Further, the pollution caused by buses is also a matter of concern in some countries. According to one of the estimates, the pollution damage caused by a bus is equivalent to that caused by 27 cars.

It follows from the above that 2-wheelers and buses are some of the major sources of pollution and therefore possible improvements in these areas should be looked at preferentially.

4. Commercially Available Battery Systems for Electric Vehicles

Electric vehicles powered by flooded lead-acid batteries with somewhat higher energy density (26-38 Wh/Kg) have been in limited commercial operation for the past two decades or more, but it is clear that this technology is not quite suitable for wide-spread implementation in both commercial and private electric vehicles. In comparison with advanced battery systems under development, the traditional lead-acid batteries would clearly be seen as deficient in its energy density for broad electric vehicle markets. However, taking an objective view of the current state of advanced battery technologies, it would appear that at least to begin with some form of lead-acid battery system would still be involved in the near term electric vehicle projects.

Lead-acid battery technology has some advantages for the electric vehicle market as seen in the next slide. The base materials are inexpensive and plentiful. Manufacturing technology exists which can be readily modified to produce large volumes of more advanced designs.

Slide # 4

Lead Acid Battery System for EVs

Advantages

Inexpensive and plentiful raw materials
Matured manufacturing technology in existence
Relatively benign from safety point of view
Infrastructure available for scrap collection and recycling
Possible to have maintenance-free version - without free electrolyte

Disadvantages

Low energy density - limited driving range
Deficient for broad DV market
Less than desired service life
Not entirely suitable for rapid recharge

However, further work is needed to improve specific energy without which it would not be possible to provide acceptable driving ranges. Extension of life is also required which may be achievable through improvements in battery/ charging technology.

Fast recharging is another area which needs some more developmental work for validation. Though there are some hazards associated with the use of lead-acid batteries, there are relatively benign from the safety point of view when compared with some of the other advanced technologies under consideration. Finally, a scrap collection and recycling infrastructure exists for lead-acid batteries, a key issue when one considers a quantum jump in the usage levels.

Furthermore, the recent advent of valve regulated lead-acid batteries (VRLA) offers considerable promise for use in electric vehicle applications. Performance levels of VRLA batteries are often higher than those of flooded lead-acid batteries. More important, they are maintenance-free, can be used in any position

and are safer due to reduced gassing levels and absence of any free electrolyte. Therefore, VRLA batteries offer a low risk, relatively low cost electric vehicle technology that can acquire a commercially viable status. However, further developments are needed for effectively 'buy time' for other advanced battery systems to improvement in the specific energy, deep cycling capability and service life. Also there is a need for development of integrated battery system for rapid recharge, good thermal management and automated monitoring and control.

In addition, some advanced lead-acid battery designs are also being considered for use in electric vehicles. For example, Chrysler plans to utilise Horizon advanced lead acid battery in their NS Mini Van EV.

Whilst most of the EV manufacturers have considered the use of advanced lead-acid batteries for their near term programmes, there are several exceptions to this approach. Nissan Motor Co., for example, have based their future electric vehicle models (FEV) on sealed Ni-Cad batteries appear to be more attractive, the cost penalties and the problems will come in the way of making them acceptable. All the same, there are several on-going EV programs based on the use of Nickel-Cadmium batteries. In addition to Nissan's FEV, Peugeot's latest car model, the ION is powered by Nickel-Cadmium batteries which can read a top speed of 105 Kmph and has a range of 150 km per charge. Likewise, Honda's electric scooter is also based on 86.4V, 20Ah Ni-Cd batteries. Similarly, an electric bus fleet of Santa Barbara, California, has been equipped with a pack of Ni-Cd batteries from SAFT, America.

5. Advanced Battery Systems for EVs.

There is an intense level of activity around the world for the development of advanced battery systems suitable for automotive propulsion. Some of the potential battery systems in the field are as follows:

Slide # 5

Advanced Battery Systems for EVs
Ovonic's Nickel-Metal Hydride Battery
Sodium Sulphur Battery
Lithium Polymer Battery
Zinc-Air Battery
Fuel Cell System for EV's
Sodium-Nickel Chloride Battery

i. Ovonic's Nickel-Metal Hydride batteries for EVs.

According to Ovonic Battery Co., their recently developed Nickel-Metal Hydride battery meets the mid-term goals of US Advance Battery Consortium (USABC). It combines some of the attractive features such as high energy density and long life with safety, fast recharging capability and maintenance-free characteristics. Ovonic have tied up with GM for production and marketing of their Nickel-Metal Hydride batteries for 4 wheeled electric vehicles and the batteries will be sold through General Motors newly formed Delco Propulsion Systems Unit. However, these batteries are relatively expensive and their initial costs are likely to be significantly higher than USABC's target price at US $ 150 per KWh.

Ovonic's Nickel-Hydride Battery for EV's

Key Features:

High Energy Density - Approximately 80 Wh/Kg

High Power Density - Aproximately 400 Wh/Kg

High Cycle Life - In excess of 600 cycles at 80% DOD

Safe and Environmental Friendly - Non-toxic & recyclable

Rapid Recharge Capability - Full charge in one hour

Relatively High Cost

ii. Sodium Sulphur Battery

Asea Brown Boveri supplied the sodium sulphur battery for use in Ford Ecostar Electric Vehicles. The demonstration programme of Ford Ecostar EV started in December'93. Whilst the programme was suspended for a few months due to fires in 2 batteries, it has been resumed from October'94. Meanwhile, Asea Brown Boveri have ceased production of their sodium sulphur batteries. However, Ford may go in for a new agreement with Silent Power which is funded by USABC for sodium sulphur research.

iii. Lithium Batteries

In Japan, the Lithium Battery Energy Storage Technology Research Association (LIBES) was formed in 1993 for a 10 year research programme with the following objectives.

- developing high energy density (180 Wh/kg) lithium batteries suitable for electric vehicles.

- Developing lithium batteries with a cycle life of 3500 for load leveling purposes.

In addition, Delco have been working with Valance under a 3 Year Programme for the development of lithium battery technology.

iv. Zinc Air Battery System

Electric Fuel promoting introduction of its zinc air battery system based on removable rechargeable battery cassettes. On completion of successful field trials, a German Postal Agency may opt for the conversion of 25,000 fleet vehicles.

v. Fuel Cells for EV applications

The US Department of Energy has awarded Ford and Chrysler 30 month long contracts to develop proton exchange membrane fuel cell systems for automotive applications.

In addition, a consortium of European companies has combined efforts to build a fuel cell bus that is currently being tested by the Transport Authority in Brussels, Belgium.

vi. Sodium Nickel Chloride Battery for Hybrid Vehicles/ Electric Hybrid Vehicles.

Volkswagen announced plans to manufacture Concept 1 model that could eventually be offered in hybrid and pure electric versions. The electric car is based on AEG Zebra Sodium-Nickel Chloride battery pack.

6. Electric Vehicles for the Indian Market

In view of the present state of EV technology and its cost structure, it would appear that the electric vehicles in their present state are not suitable for wide-spread implementation in the Indian market. At the same time, there is a pressing need to come up with some effective measures for combating the rising pollution levels especially in the metropolitan cities. Clearly the electric vehicle programmes in India will have to be selective and sharply focused.

Two potential areas for the introduction of electric vehicles in the country would appear to be:

a. 2 wheeler/ 3 wheeler segment and

b. Select range of buses such as special purpose buses for schools, airports, recreation parks etc.

From practical consideration, the user of a two-wheeler is more likely to compromise on the range between the charges in view of the normal usage pattern, i.e. limited driving, lower speeds and availability of required idle time for charging etc. In general, the user of a two wheeler is less demanding as compared to a car owner. In short, the logistics appear to be more in favour of two wheeler type of electric vehicle for India.

In addition, potential applications for EV's would include special purpose buses. As stated by the Chairman andCEO of Bluebird, USA, "School use is ideal for electric powered vehicles because schools have a standard operating range and the bus can be recharged during the evenings when the power costs are less".

As regards manufacturer of electric 2 Wheelers, some indication of the prospective manufacturers is given in the next slide.

Slide # 7

Manufacture of Electric Two Wheelers

International Scenario - Some of the Prospective Manufacturers:

* **Electric Option Corporation,** Littlerock, California, USA.
  Plans to manufacture 100,000 Electric Scooters per year in India followed by mopeds and three wheelers.

* **Kwang Yang Motor Co.,** Taiwan

  Announced plans to manufacture 50,000 to 60,000 Electric two wheelers in Taiwan having 65 Km range at approx. 33% higher cost than petrol versions.

The development of electric 2 wheelers has been taken up seriously in Taiwan in view of the increasing congestion in the city centres like Taipei where the traffic speed has been reduced to 14.9 Km per hr. The design parameters for the development of electric 2 wheeler in Taiwan are as follows:

Slide # 8

Electric Two Wheeler Developoment in Taiwan

Vehicle Design Parameters :		
Vehicle Range	:	60-80 Km
Max Speed	:	50 Km/hr
Acceleration	:	0 - 30 Km/hr in 6 sec
Gradeability	:	21%
Motor	:	1.5 KW, DC Brushes, 6000 rpm max.
Transmission	:	Automatic
Efficiency	:	85%

The batteries used are obviously sealed maintenance free type (VRLA). In all, four 12 V units are used in series to achieve a system voltage of 48V. the broad parameters of the VRLA battery used for this application are shown in the next slide.

Slide # 9

Electric Two Wheelers Battery Development in Taiwan

Design Parameters:		
Battery Type	:	Sealed MF (VRLA)
System Voltage	:	48 V
Battery Capacity	:	12 V28 Ah at 3 hr. rate
Battery Weight (12 V Unit)	:	10 Kg
Cycle Life	:	330 minimum at 80% DOD
Battery Rechargeability	:	30% recharge in less than 15 minutes

In addition, a small electric car manufactured in Surrey, UK has also envinced considerable interest in India. Designed with 4 independent DC motors and micro processor controlled 4 wheel drive, the small car has a range between 80 - 100 Km with a maximum speed 45 - 50 Km/hr. It is felt that such a car could be considered as a replacement for our present 3 wheeler powered by 2-stroke petrol engines. The small car is powered with tubular lead-acid batteries with details as follows:

Slide # 10

Hed Battery for Small Electric Car Ex-surrey, UK

Battery Type	:	72V 170Ah (Tubular)
Battery Size	:	1015 (L) x 630 (W) x 265 (H)
Assembled In	:	Steel Tray
Energy Density	:	40 Wh/Kg approx.
4 Independent DC Motors Micro-processor Controlled 4 Wheel Drive Chopper Control, FRP Body		
Range:80 - 100 KM Max. Speed	:	45 - 50 Km/ hr

As regards the electric bus operation, it would perhaps be desirable to have a provision for a change of battery during the day to extend the range. This approach is not uncommon; Neoplan electric bus under trial in Germany appears to be based on this concept. The specifications of the battery used for this bus are shown below:

Slide # 11

Varta Perfect H Battery for Neoplan Electric Bus

Battery Type	:	4 PzS 320 H
Battery Voltage Capacity	:	144V 320 Ah at 5 hr rate
Battery Size	:	1630 x 800 x 520 mm
Battery Weight	:	1573 kg with tray
Energy Density	:	30 Wh/kg approx.
Specification	:	As per DIN 43595

The system voltage and battery capacity of Neoplan bus are not largely different from those proposed by BHEL for their 40 passenger battery bus under development. The BHEL electric model is based on 156V 300 Ah battery system to give a range of upto 70 Km.

In addition to VARTA Batteries, Classic 25 range of Chloride Motive Power, UK and CEAC's Acifit motive power range for the EVs may also be considered suitable for the purpose. Some details are shown in the next 2 slides.

Slide # 12

Chloride Motive Power Classic 25 Range for EVs

Potential Battery Types for Buses:

Cell Type	Capacity	Cell Weight	Cell Dimension
S26 Y (17 plates/cell)	420 Ah	22.4 Kg	119 x 198 x 370 mm
S36 Y (9 plates/cell)	300 Ah	16.5 Kg	65 x 198 x 500 mm

Expected Cycle Life : 1000 at 80% DOD

Slide # 13

CEAC's Partial Acifit Range for Electric Vehicles

Battery Type	Weight	Dimensions
6V - 225 Ah	32 Kg	317 x 186 x 250 mm
6V - 100 Ah	20 Kg	246 x 167 x 224 mm
12V - 100 Ah	46 Kg	437 x 172 x 295 mm
12V - 85 Ah	40 Kg	345 x 174 x 283 mm

Cycle Life : 800 - 1000 at 80% DOD

Energy Density : 40 Wh/kg Plus

7. Possible Electric Vehicle Battery Development by CIL

There is an urgent need to assess the market potential of a few select electric vehicle models for use in India such as 2/3 wheeled scooters and special purpose electric buses etc. Identification of potential models should immediately be followed by field trials to assess their suitability for the Indian conditions.

Once the ground work has been done and the specifications are frozen, it should be possible to undertake the development and supply of batteries suitable for EV applications in India as shown in the next Slide.

Slide # 14

Possible EV Battery Developments by CIL
72V 170AH HED Lead-Acid (Tubular) battery for small electric car
96V 300 AH HED Lead-Acid (Tubular) battery for BHEL's Electra Van/Electra Bus
Sealed lead-acid (VRLA) battery for electric two wheeler
144V 320AH lead-acid (tubular) battery for electric bus
New generation EV battery through collaboration/joint venture

Finally, no EV project at present can succeed without adequate fiscal incentives such as exemption from customs and excise duties etc. Furthermore, new legislations are required for upgrading the present emission standards especially in the 2-wheeler sector.

Batteries for Powering Electric Vehicle

Dr. R. Gangadharan
Head, Batteries & Fuel Cells Division
Central Electro Chemical Research Institute
Karaikudi

1. Introduction

The electric vehicles concept for transport has driven by two principal factors over the past two decades. The first factor is the oil crisis which is occurred in the year 1970 and the second is the environmental awareness and elimination of pollution from surroundings.

Although the oil crisis is not immediate, it may occur in another quarter of a century. The number of vehicles driven by the fossil fuel is increasing year after year in the world and in India also the number of IC vehicles increase for utility. Hence, there is potentially significant future problem with almost total reliance on oil supplies for transport needs.

In 1980's the global awareness to keep the environment free from pollution came from all quarters of the world. Hence, there is increased pressure from all governments to keep the surroundings free from pollutants. The emission of CO, CO2, N2 and NO are kept at a minimum level from the automobile exhause. Stringent governmental regulations are enacted to keep the automobile pollutants to zero level.

Electric vehicles offer the possibility of widening the portfolio of fuels used for road transport while reducing the local emissions.

2. Market for electric vehicles

In order to create a market for electric vehicle, in the automobile sector in advanced countries like Japan, Germany and USA, it is necessary to enact laws by Governments so as to initiate a market and these may stimulate the development of vehicles.

In USA and Japan there are high level Government action committees aimed at establishing an electric vehicle market. However, the policies of these countries in the governmental side may vary but the aid is the same. France is the only European Country where government has given a lot of support for electric vehicle activity although the other countries have taken only limited concessions in this direction.

As a result, despite the initial electric vehicle market started in a small way in many countries of Western Europe, at least for some time there will be no significant increase in sales of electric vehicles which can compete effectively with the petroleum driven vehicles. Therefore, from advanced countries like Japan and USA there should emerge a good market for these vehicles by improving the performance and reduction of cost which will stimulate further activity in this area. However, it is expected that until the turn of this century the reduction of cost and performance of the electric vehicle will be limited. But, by further technological advancement, it is possible to reduce the cost and performance of these vehicles in the beginning of 21st century.

3. Global Scenario

It is anticipated that in Japan, USA and Europe the sales of electric vehicles will increase year after year. The main places of application of EV are postal delivery vans, milk vans, school vans and general usage. In 2010, the largest single market in USA with anticipated sales of 1 million per annum, 60000 in Japan and 50000 in Europe will boost up the market for EV. The Californian Emission Legislation requires 2% of vehicle sales in California, to be ZEV (Zero Emission Vehicle) in 1998. It is expected other states in USA will follow suit and thus sales of EV will go up considerably.

Forecast of the electric vehicle made by MIRA is shown in the table 1.

Table 1

Year	Country		
	No. of Electric Vehicles		
	Japan	W. Europe	USA
1995	4,800	2,500	1,000
2000	7,400	3,700	16,000
2005	27,000	22,000	70,000
2010	50,000	60,000	100,000

Source MIRA - Electric Vehicle Forecast

4. Indian Scenario

The concept of electric vehicle gained momentum in India one and half decades back. CECRI and BHEL are the pioneers in the area of activity. BHEL has trial demonstrated several electric vehicles in Delhi to show its efficiency, road worthiness and that they are noise and pollution free. More than 100 EV are in operation. In the transport sector, we have scooters, motorcycles, passenger cars, medium and heavy commercial vehicles run by petroleum drive vehicles. In urban areas mopedes, scooters and triwheelers are used in large numbers. Table 2, 3,4 & 5 (taken from Hindu 1993) the the population of vehicles in our country.

Table 2

Scooters

Name of the manufacturer	1989-90	1990-91	1991-92
Andhra Scooters	1019	335	—
Bajaj Auto	539731	552162	492079
Gujarat Narmadha	28381	21397	4384
Kelvinator	307	173	104
Kinetic Honda	60490	76849	87477
LML	148231	156891	88628
Maharashtra Scooters	101251	104152	97161
Total	879410	911959	769833

Source: Hindu 1993

Table 3

Motor Cycles

Name of the manufacturer	1989-90	1990-91	1991-92
Bajaj Auto	85822	122648	117461
Enfield	25010	28185	26967
Escorts	156892	153863	117634
Hero Honda	96191	120150	135001
Ideal Jawa	12156	5848	—
TVS Suzuki	39276	37042	33744
Total	415347	467644	430807

Source : Hindu 1993

Table 4

Medium & Heavy Commercial Vehicles

Name of the manufacturer	1989-90	1990-91	1991-92
Ashok Leyland	21683	24123	23210
Hindustan Motors	1077	276	25
Telco	52901	60852	61908
Total	75661	85251	85143

Source : Hindu 1993

Table 5

Passenger Cars

Name of the manufacturer	1989-90	1990-91	1991-92
Hindustan Motors	28624	23021	17263
Maruti Udyog	107840	111860	118083
Premier Auto	42370	42561	30887
Jipani Auto	212	500	—
Total	179046	177942	166233

Source : Hindu 1993

In India the rate of consumption of petrol shows that the available petroleum resources will last for only 16 years where as the world resources will exist for two and a half decade. Hence, it is necessary to give philip to the EV activity in our country. Since other countries in the world are showing lot of impetus in this direction we should also rise to the occasion.

5. Present position fossil fuels

Energy, without which no transport is possible. In the earlier days, different forms of materials were used to produce energy. Petroleum, methanol and natural gas are the forms of energy used in IC engine to drive the vehicle. Due to indiscriminate use of energy for transport, resulted in its depletion from the earth and in another quarter of a century, it is expected that this fuel will not be available for the younger generation for transport. Therefore, scientists are worried and search is made to find out another form of energy for transport purpose.

6. Alternate fuels

Methanol, natural gas, compressed gas, hydrogen, electrochemical power source, fuel cells and hybrid cells are other sources of energy used to drive a vehicle. Also there are various forms of electrochemical power sources for driving the vehicle. Of these, lead acid and alkaline nickel-cadmium cells are chosen as the conventional cells whose production in large quantities in industry has stabilized throughout the world. Many transformation in designs have taken place in these systems. While every effort is made to increase the energy density of these batteries, due to thermodynamic limitations, it is not possible to increase the value more than 40Wh/kg. There are inherent limitations in lead acid battery, namely, overcharging, undercharging, fast charing, electrical abuse, sulphation, drying up of cells and cycle life. Nickel-cadmium cell is superior to lead acid in these respects but cost wise this balance is tilted in favour of plante cells.

7. Electrochemical energy producing devices

Batteries are electrochemical power pots which generate electricity continuously by chemical reactions. There are several systems generating electric energy. Of these Pb acid alkaline cells like Ni-Cd, Ni-Fe, Ni-Zn and Ni-H2 and Ni-metal hydride, Na-S, Zebra cells, Zn-Br2, Zn-air, Li-FeS2, Li-Swing system and Li-polymer electrolytes cells are the most important systems. these systems are considered for electric vehicle propulsion purposes. Pb acid battery s a very old system. It has already established a base in all industrial places in our country. there are more then 7 organised industrial units producing millions of lead acid cells. In addition to this small scale units manufacture an equal number cells in our country. The question of using this battery for EV is not much favourable from the point of the following:

1. Limitation of overcharging
2. Limitation of undercharging
3. Limitation of Fast charging
4. Sulphation
5. Low energy density
6. Health hazard and pollution of Pb

Several research activities to over come these difficulties are attempted. But some of the inherent problems are not solvable. Several improvements are made in the recent years by USABC to use Pb acid battery for EV.

Ni-Cd is one of the finest systems in the battery area for EV activity. The advantages of the Ni-Cd system is fast charging, electrical abuse and over/under charging and dry up of cells. All these factors will not affect the cell performance. However, cost is a factor which can to a certain made matching by cycle life of the cell. Hence, Ni-Cd can be considered as a good cell of EV. Several improvements like fibre bonded

electrodes, FNC electrodes maintenance free & bipolar electrodes make the systems superior to Pb acid.

Ni-Fe cell system is also be considered similar to Ni-Cd system for EV purpose. The self discharge rate of the cell is the only working problem of Edson cell. However, all these there conventional systems suffer from low energy density problem.

8. High energy density batteries for EV

High energy density batteries are those systems which give more than 100 Wh/kg. Na-S and Li batteries are considered as high energy density battery systems. Na-S and Zebra cells and Li-FeS2 are high temperature cells. Although they show high energy density and power density their use is not much favoured due to higher temperature of operational performance.

Recently lithium cells are considered as batteries for EVs. Two important systems are suggested.

1. Swing or Rocking chair or lithium ion cells
2. Lithium polymer cells

9. Rocking chair batteries

Rocking chair or lithium ion batteries or swing cells as they are called by different names for a carbon/lithium manganate cell of 4.0V has attracted the power source researchers. These cells show high voltage and high power besides being environmentally safe unlike all conventional secondary cells like Pb acid, Ni alkaline cell series.

The advantages of this cell are given below:

1. small in size
2. reduces space
3. reduces volume
4. high energy density
5. high power density
6. explosive free
7. environmentally safe
8. inexpensive
9. cheap materials available in our country

The latest cell in this area of C/Li+/organic electrolyte/ LiKVO4. This cell shows a voltage of 4.8V. The cell consists of carbon electrode as anode with Li potassium vandate a cathode. The cells swings in between valencies of V3 and V4 during discharging and charging process of intercalation/ deintercalation. LiCoO2, LiNiO2 & Li2Mn2O4 cathodes also show swinging valencies during cycling. Several useful gadgets can be operated with lithium ion cells.

10. Polymer cell

In the recent years polymer cell has been identified as the most important energy producing device for running the vehicle. There are some positive aspects to this system. They are (1) low cost, (2) total elimination of Li metal i.e. intercalating Li on carbon anodes, (3) avoidance of explosive hazards, (4) solid electrolyte, (5) can be kept in any position for delivering the current, (6) high energy density, (7) high power density and (8) saves space and volume.

In lithium polymer electrolyte system intercalated carbon electrode acts as anode. Polymer electrolyte acts as conducting medium. Li-manganate acts as a cathode and this replaces the existing V6) 13 compound.

A thin electrode film made out anode, electrolyte and cathode makes the system compact in shape and form. These electrodes and electrolyte are easier to handle and their material cost can be considerably reduced. It is anticipated that these cells can be compacted in the form of a box which can be kept under the drivers seat for running the vehicle. The total weight of the polymer cell system will be around 40kh. If the weight of the vehicle is assumed as 1 ton, the weight of lead acid battery will be around 350 kg (35% of the weight of the vehicle is attributed to batteries. If we switch over to lithium polymer system we may save space, materials, and cost. Many researchers throughout the world are experimenting to develop this system for running the vehicle. Many companies have actively interested to make a commercially viable lithium polymer cell. It is anticipated that in another two years polymer cells will make in entry in the commercial world of Electric Vehicle.

Cathode Reaction

$$LiMn_2O_4 \xleftrightarrow[\text{Discharge}]{\text{Charge}} Li_{n-x}Mn_2O_4 + X\,Li^{+} + Xe^{-}$$

Anode reaction

$$C + X\,Li^{+} + Xe^{-} \xleftrightarrow[\text{Discharge}]{\text{Charge}} Li_xC$$

The Li-intercalation process in "rocking-chair" cells involve three principal steps:

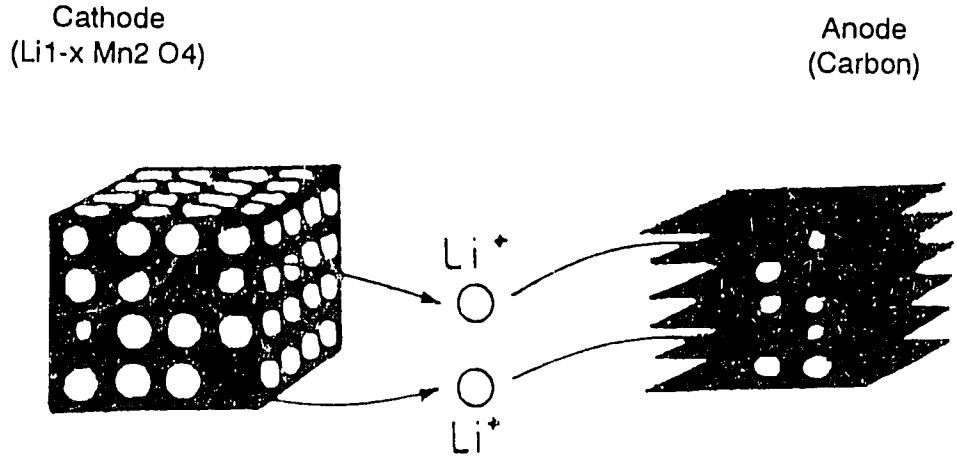
diffusion or magration of solvated Liions to the Helmholtz plane of the double layer at the host lattice

desolvation and injection of Li ions into the vacancy structure at the near surface of the host, and

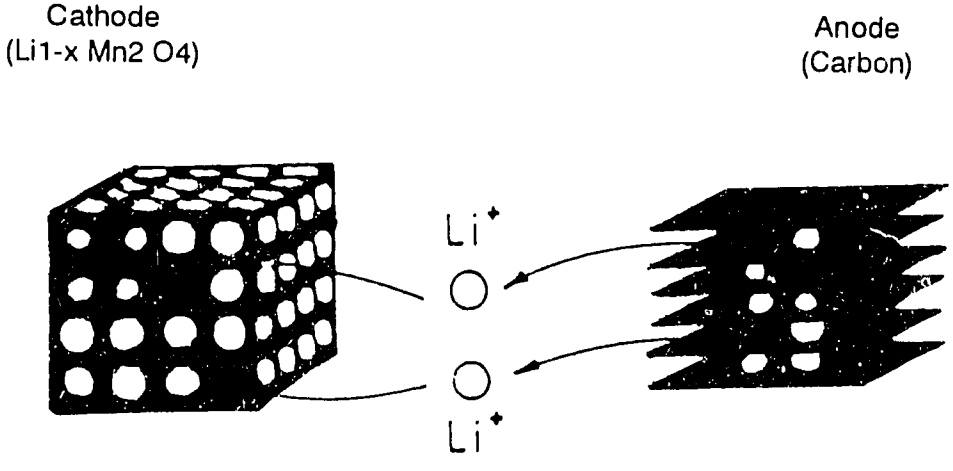
diffusion of Li ions into the bulk of the host lattice.

Source : R. Gangadharan et;al.

CHARGE



DISCHARGE



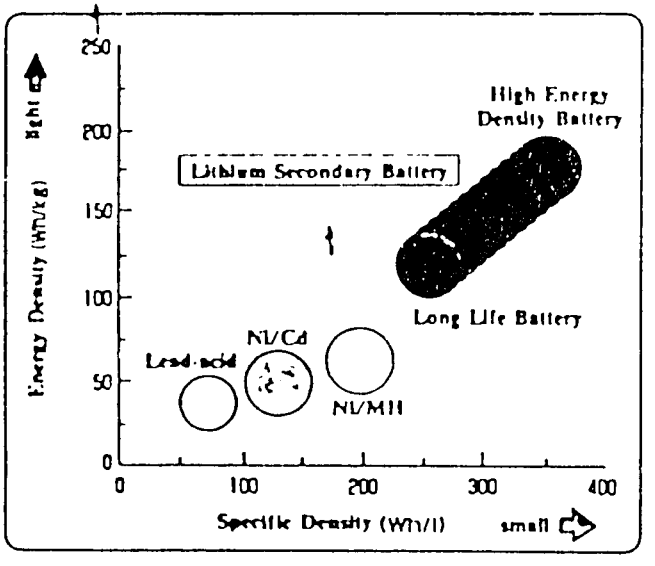
The Charge-discharge Mechanism for Rocking-Chair Battery

Source : R. Gangadharan et;al.

Characteristics of Lithium Secondary Battery

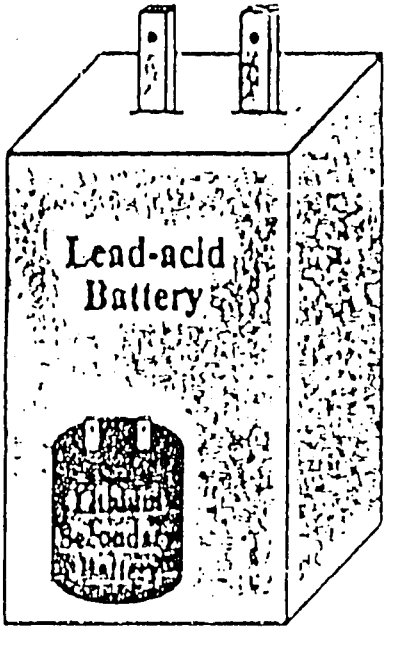
1 Light-Weight

Weight of lithium battery is 1/3-1/5 of lead-acid battery for storing the same energy capacity.



2 Small-Size (Compact)

Volume of lithium battery is 1/3-1/5 of lead-acid battery for storing the same energy capacity.



Source : Polymer Electrolytes
B. Scrosati

3 High Cell Voltage

----- able to reduce required number of cells

Voltage of a lithiurn cell is 3-4, and it is 1.5-2 times higher than that of lead acid battery

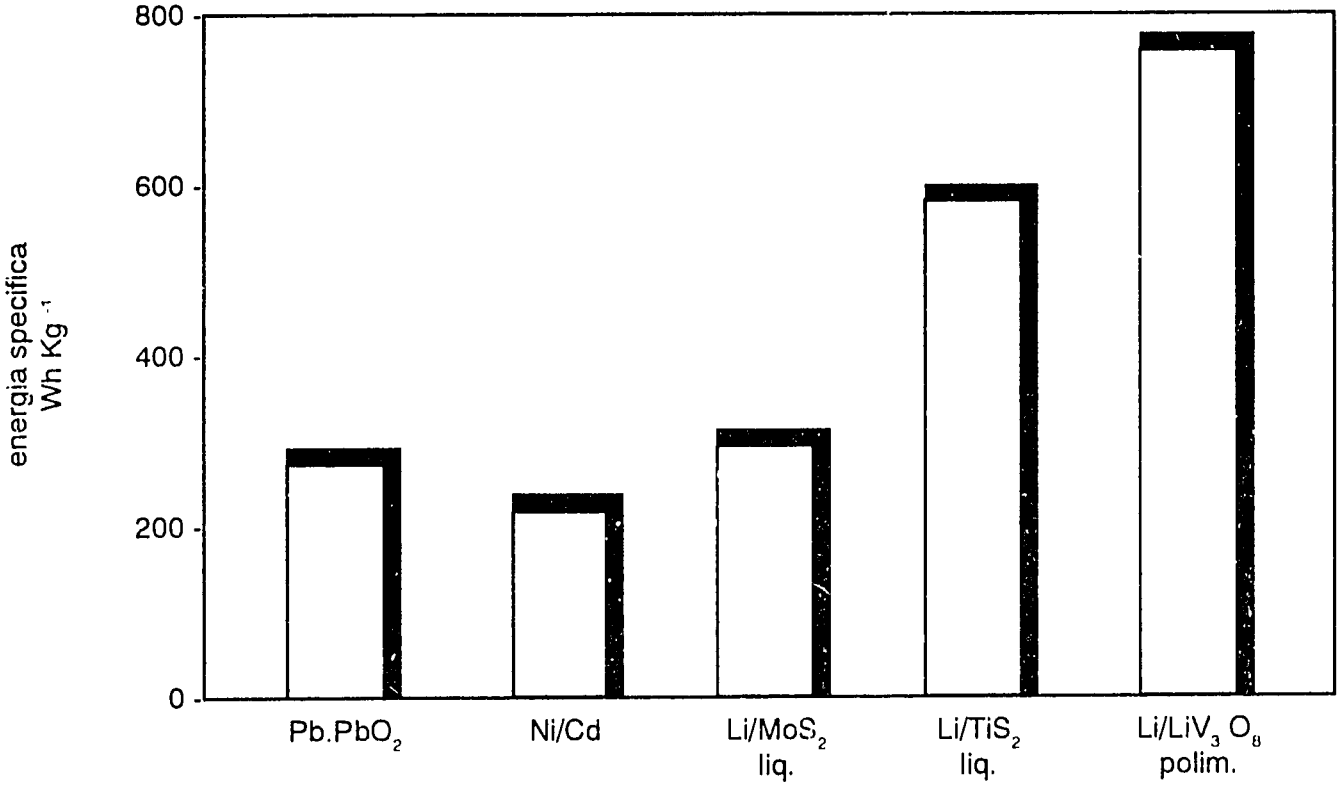
4 Wide Temperature Range

Lithum battery is availabie to use in the range of -20-60°C. It also has good charge/discharge characteristics from low to high temperature.

5 High Maintainability

Lithium battery is perfectly sealed, and has high, maintainability.

Source : Polymer Electrolytes
B. Scrosati



Cafronto tra i contenuti teorici massimi di energia specifica (wh kg^{-1}) di accumulation.

Average Battery Characteristics & Coals
(Values are based on a Geo Prism size vehicle, 31 Wh/mi.m battery pack wt.=450 kg)

Type Battery	Energy Wh/kg.	Power W/kg	KWH	Cycles	Range Miles	Cost $/KwH	Total Cost $	Total Mile
Standard Lead Acid	35	110	16	400	52	100	1,575	20,000
Advanced Lead-Acid	40-50	150-400	19	>600	63	150	2,835	35,000
Nickel Cadmium	53	160	24	>1000	80	400	9,540	80,000
Nical-Metal Hydride	80	200	29	1000	98	250	7,312	100,000
Sodium Sulfur	110	150	43	600	143	250	10,688	85,000
Sodium Nickel Chloride	100	150	45	1000	150	250	11,250	150,000
Lithium Ion	>100	150	45	1000	150	200	9,000	150,000
Zinc-Air	180	125	81	200-400	270	125	10,125	110,000
Lithium Polymer	200	400	90	1000	300	100	9,000	300,000
Lithium Iron Disulfide	200	400	90	1000	300	100	9,000	300,000
Alabc, Goals	50	200	23	600	77	150	3450	46,200
Usabc Mid-Term	80-100	150-200	36-45	600	120-150	150	6000	80,000
Usabc Long-Term	200	400	90	1000	300	100	9000	300,000

Source : Yardney Co. Brochure

Li-Ion Rechargeable Batteries
Performance Comparison of Rechargeable Batteries

Parameters	C/LICoO$_2$ **	NICd	Pb-Acid	Nim-1	Li/MnO2	LI/SO$_2$
Average Voltage	3.6V	1.2V	2.0V	1.2	2.8	3.0
Energy Density	115 wh/kg 250 wh/l	35 100	25 75	50 175	100 220	150* 272*
Cycle Life	1200	800	500	<500	200	250
Self-Discharge (% per month)	10%	25%	5%	7%	1%	<1%

* Projected Value

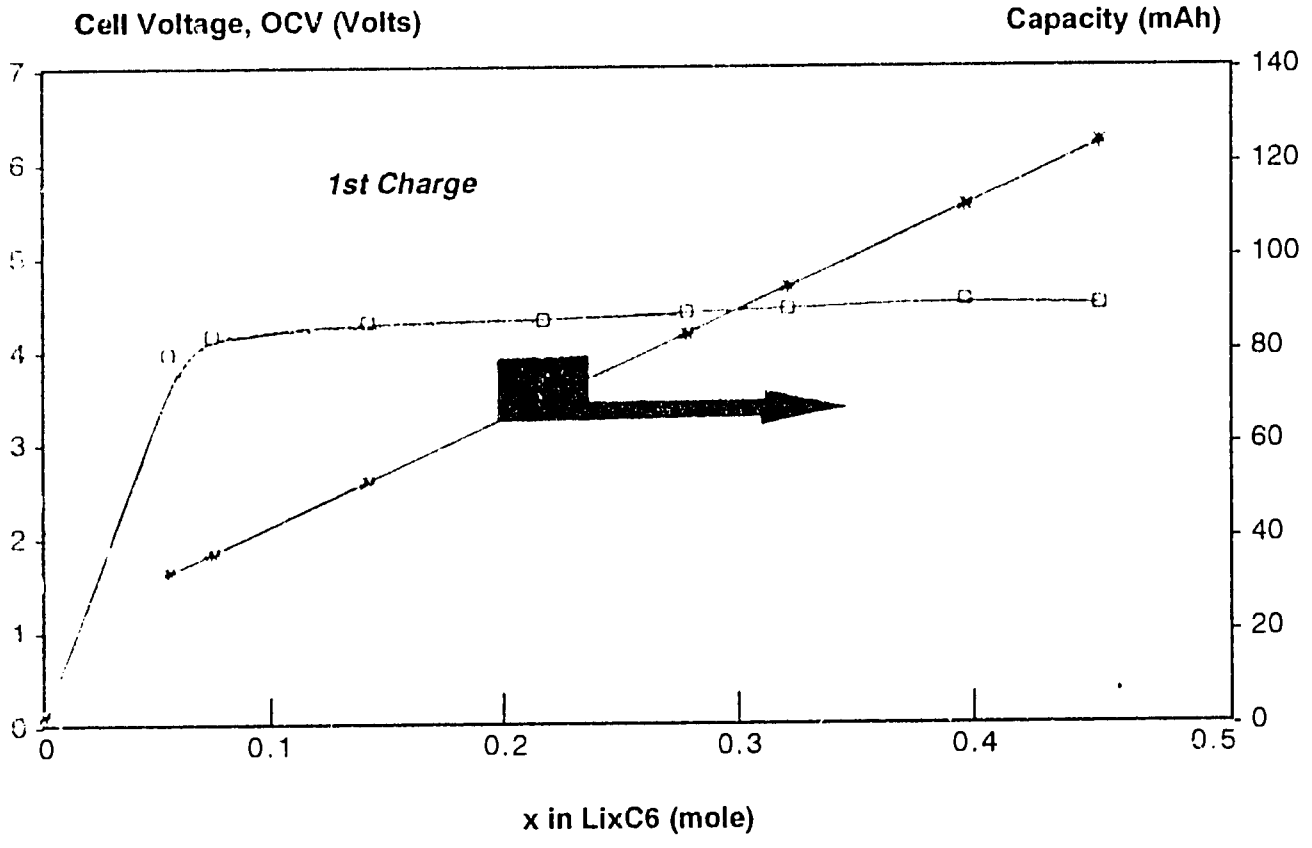
** Lithium Ion

Source : Yardney Co. Brochure

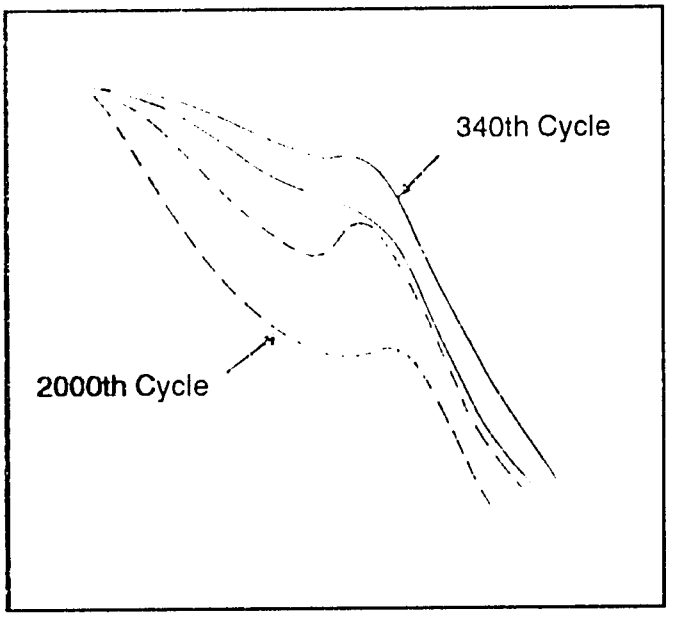
Target Performance

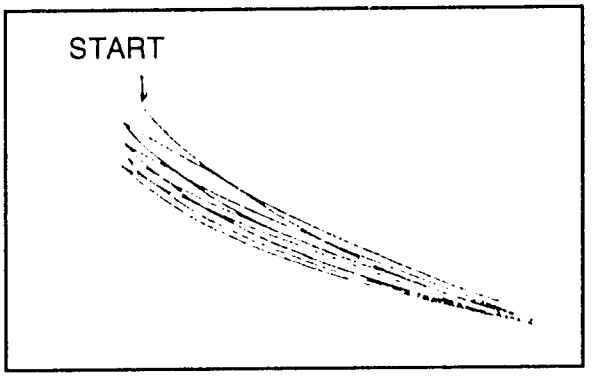
	Long Life Li Battery	High Energy Density Li Battery
Energy Density (Wh/kg)	120	180
Specific Energy (Wh/l)	240	360
Life (cycle number)	3,500	500
Energy Efficiency (%)	> 90 =	> 85 =
Usage	Load Levelling System for Home use10	Electric Vehicle

LiMn 204/1m LiClO4 (DMC/EC/PC)/Graphite



Current (arbi. units)





Source : *R. Gangadharan et., al.*

Melting point and heat of fusion data for P (VdF-HFP) copolymers

(co)polymer[a]	mole ratio VdF. HFP	DSC m.n. °C
VdF HMW	100	170
VdF MMW	100	160
VdF-HFP	94:6	155
VdF-HFPHMW	88:12	143
VdF-HFP MMW	88:12	138
VdF-HFP	85:15	135
VdF-HFP	75:25	NM
VdF-HFP-TFE	?	90

a) HMW = high mol. wt.; MMW- med. mol wt.

Source : Bellecore

Physical appearance of solvent-cast films from various polymers plaisticzed with 50 wt.-% of $LiPF_6$-EC/PC

polymer matrix	comments[a]
ploy(methyl acrylate)	tacky
poly (methyl methacrylate)	tacky
poly (styrene-acrylonitrile)	tacky
polycarbonate (low MW)	very brittle
NBR and SBR rubbers	electroc, unstable
poly (vinyl acetate)	very tacky
poly (acrylonitrile) in DMF)	high-temp proc.
poly (vinyl chloride)	(PVC) strong, clear
P(VC-VdC)	strong, clear
PVdF (various mol. Wts.)	PS, insluble
P(VdF-6-15% HEF)	strong clear
P(VdF-25% HFP) (Viton	viscous liquid
PVdF-HFP-TFE	weak, PS

a) PS=phase separation

Source : Bellecore

Characteristics of various electrolyte systems for Li and Li-ion batteries

electrolyte	advantages	disadvantages
liquid	high ionic conductivity; well-established technology	liquid leakage; metal can; expensive separator; electrolyte oxidation
Solid	no electrolyte leakage; polymer processing methods	low ionic conductivity; poor mech. properties; difficult to purify
hybrid	high ionic conductivity; polymer processing; no leakage; controlled conductivity	compatibility mech. creep; electrochem. stability

Source : Bellecose

Ovonic Nickel-Metal Hydride Batteries : The enabling technology for Electric Two and Three Wheelers in India

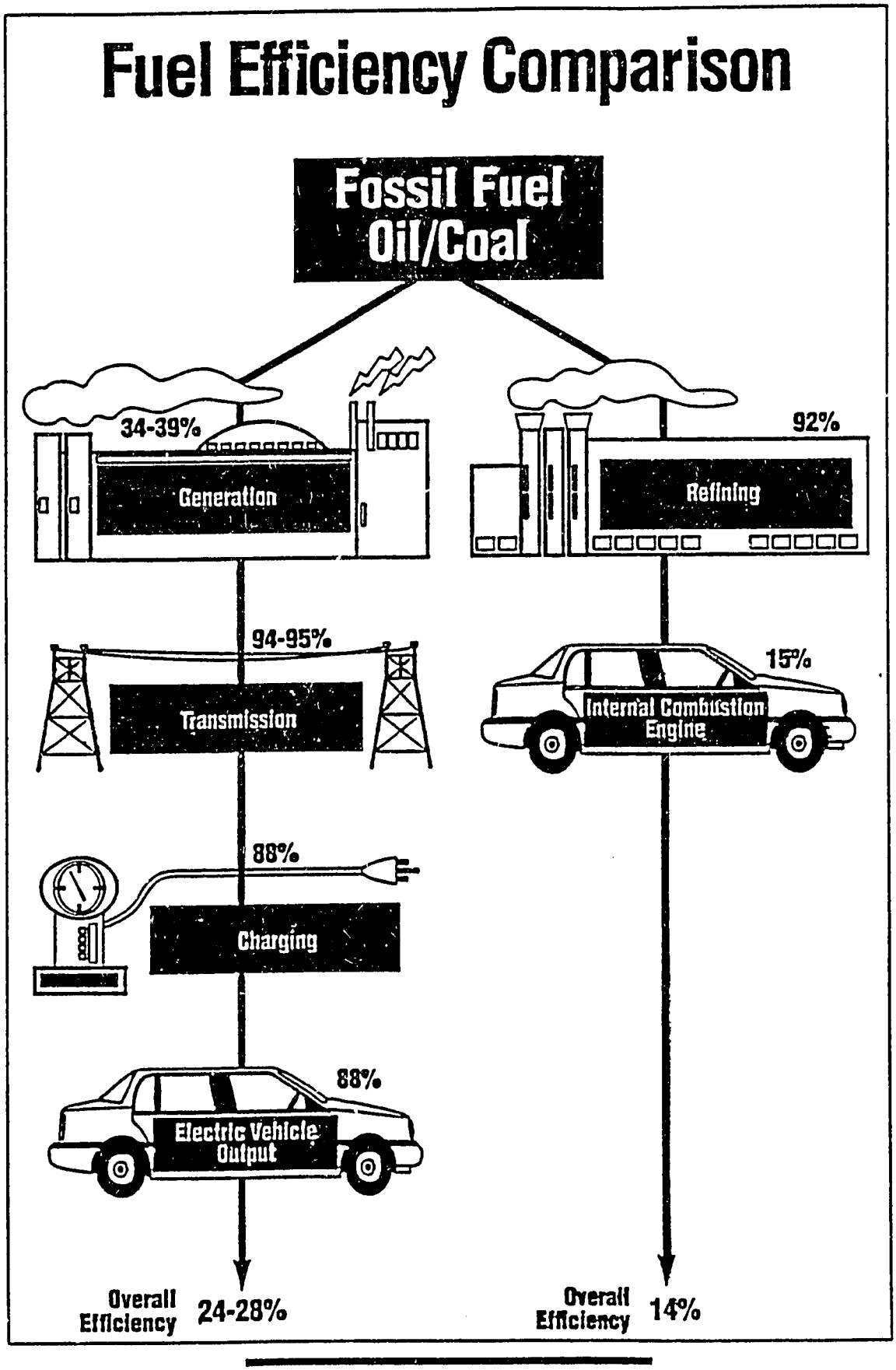
Mr. Subhash K. Dhar
Ovonic Battery Company
Troy, Michigan, USA

ELECTRIC VEHICLES FOR INDIA

Benefits:

- Independence from foreign oil
- Improved energy efficiency
- Improved air quality
- New industry
- Technological leadership

The Green Battery OVONIC



ELECTRIC SCOOTER

OPERATING COST COMPARISON

	GASOLINE	OVONIC NiMH
RANGE	160 km	90-120 km
FUEL COST	$2.26	$0.17- $0.22¢
¢/km	1.4¢	0.20¢

*Based on gasoline at $1.13/gal, electricity at $0.08 /kWh for off-peak overnight charging

TWO AND THREE WHEELED VEHICLES MARKET POTENTIAL

REGION	TOTAL 2 & 3 WHEELERS	ANNUALGROWTH
Europe	7.2 Million	0.2 Million
Japan	14 Million	3 Million
Taiwan	8 Million	1.2 Million
India	9.8 Million	1.7 Million
Total	39 Million	6 Million

20% Mkt Share = $360 million/year

INDIAN MOTOR VEHICLE MARKET

	Year	Two-Wheelers	Three-Wheelers	Car, Tax, Jeep	Bus	Other	Total Vehicles
Calcutta	1986-87	39%	1%	48%	1%	10%	351,000
Bombay	1986-87	36%	8%	49%	1%	7%	524,000
Delhi	1986-87	69%	3%	20%	1%	6%	1,112,000
Madras	1986-87	63%	2%	26%	1%	8%	373,000
Bangalore	1986-87	72%	3%	19%	2%	5%	359,000
Ahmedabad	1986-87	71%	12%	12%	2%	3%	232,000
Hyderabad	1986-87	77%	5%	11%	1%	6%	303,000
Pune	1986-87	72%	7%	11%	1%	9%	213,000
Kanpur	1986-87	80%	2%	8%		10%	127,000
Nagpur	1986-87	79%	3%	10%	1%	8%	98,000
Jaipur	1986-87	66%	2%	14%	4%	14%	163,000
Lucknow	1986-87	77%	1%	10%	1%	11%	124,000
Madurai	1988-89	70%	1%	14%	2%	12%	53,000
Patna	1987-88	71%	4%	24%	1%	10%	73,000
Coimbatore	1987	81%	2%	12%	1%	4%	150,000
Vadodara	1987-88	70%	6%	11%	5%	8%	188,000

Source: Tata Transport Annual, 1991

INDIAN AIR POLLUTION EMISSIONS

(by vehicle class in g/km of travel)

Vehicle	CO	HC	NOx	Total
Car	24.03	3.57	1.57	29.17
Two Wheel	8 3	5.18	–	13.48
Three Wheel	41.5	25.9	–	67.40
Bus	–	–	–	87.20

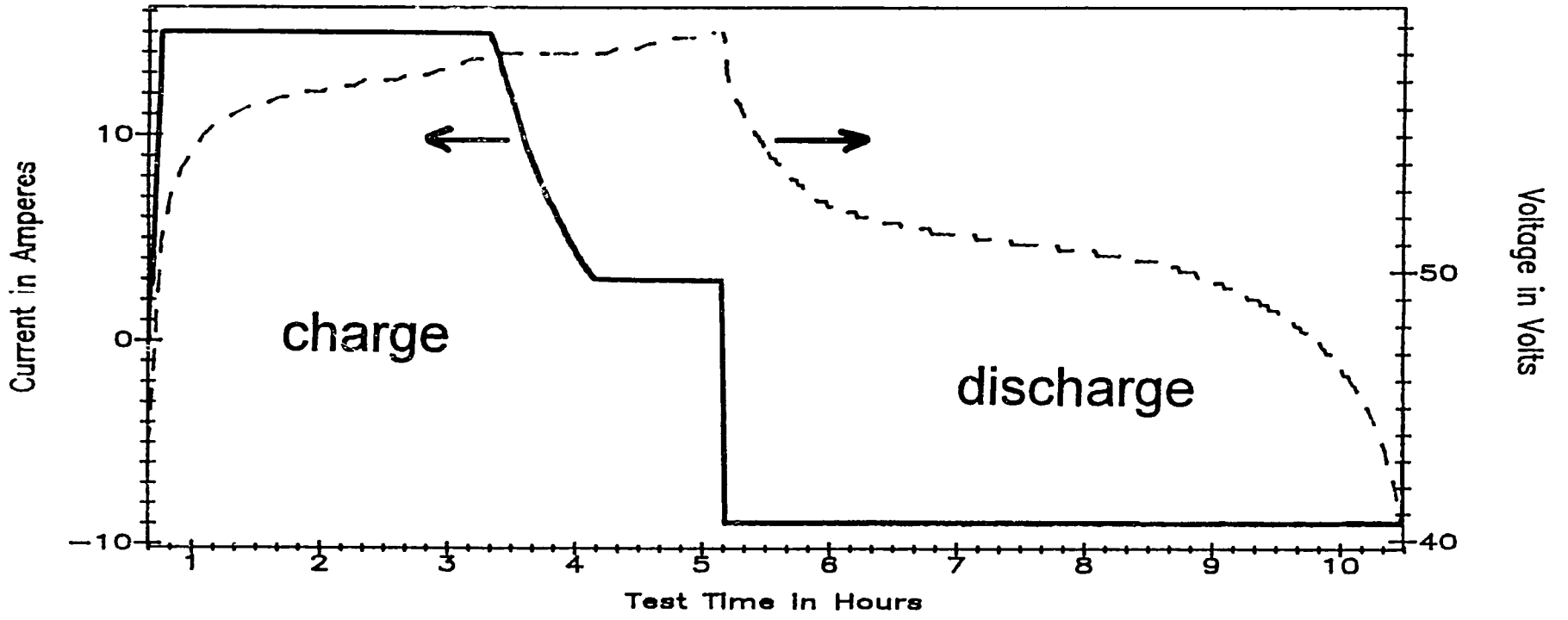
KEY CRITERIA FOR EV BATTERIES

1. Energy
2. Power
3. Durability
4. Ruggedness
5. Rapid Recharge
6. Maintenance
7. Environmental Compatibility

OVONIC NiMH BATTERY PACK FOR 2-WHEELER ELECTRIC VEHICLES

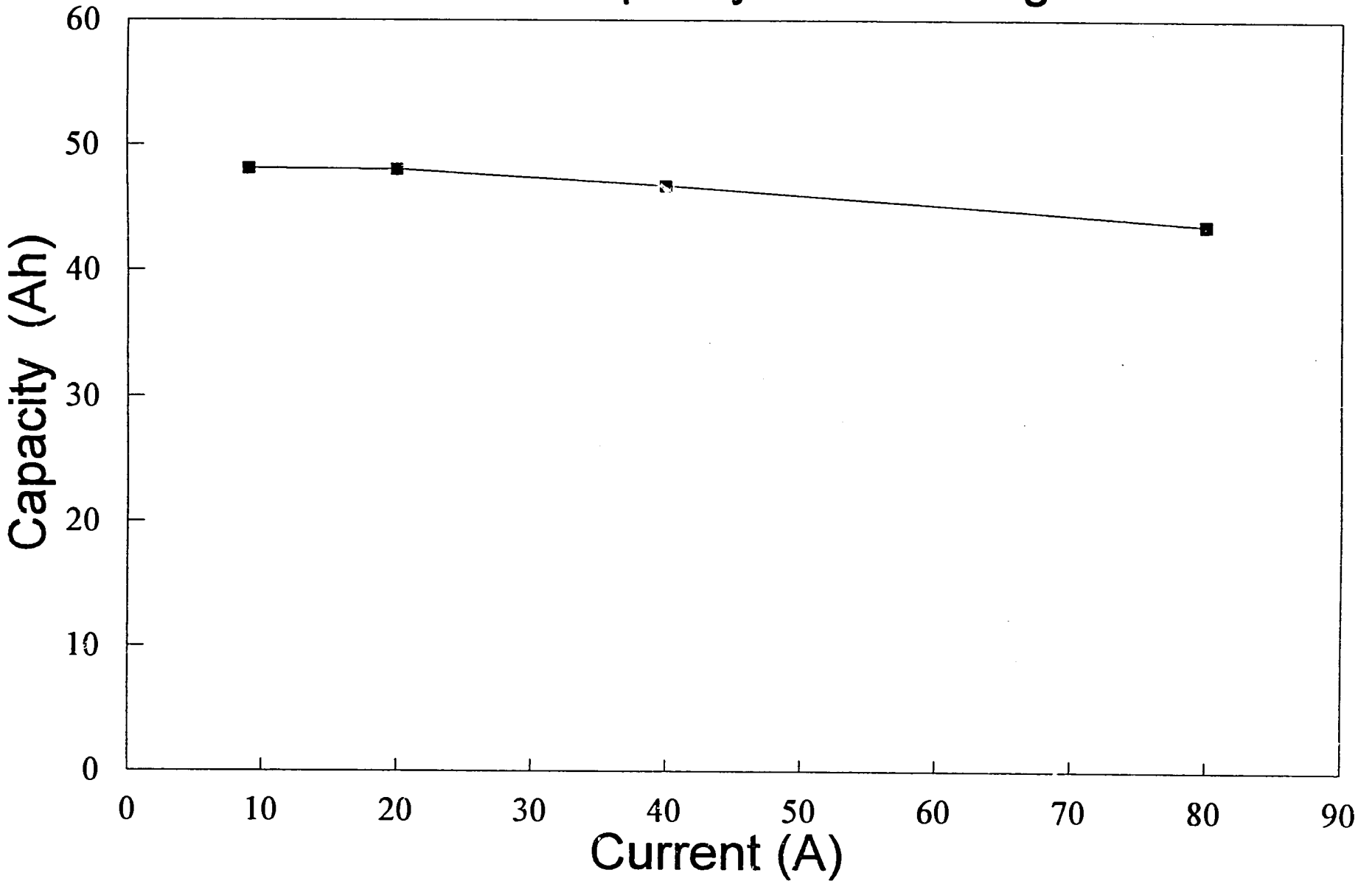
Voltage	=	48 V
Capacity	=	50 Ah
Energy	=	2.5 kWh
Power	=	10 kW
Weight	=	35 kg
Volume	=	15 L

Charge-Discharge of 2-Wheeler Battery Pack

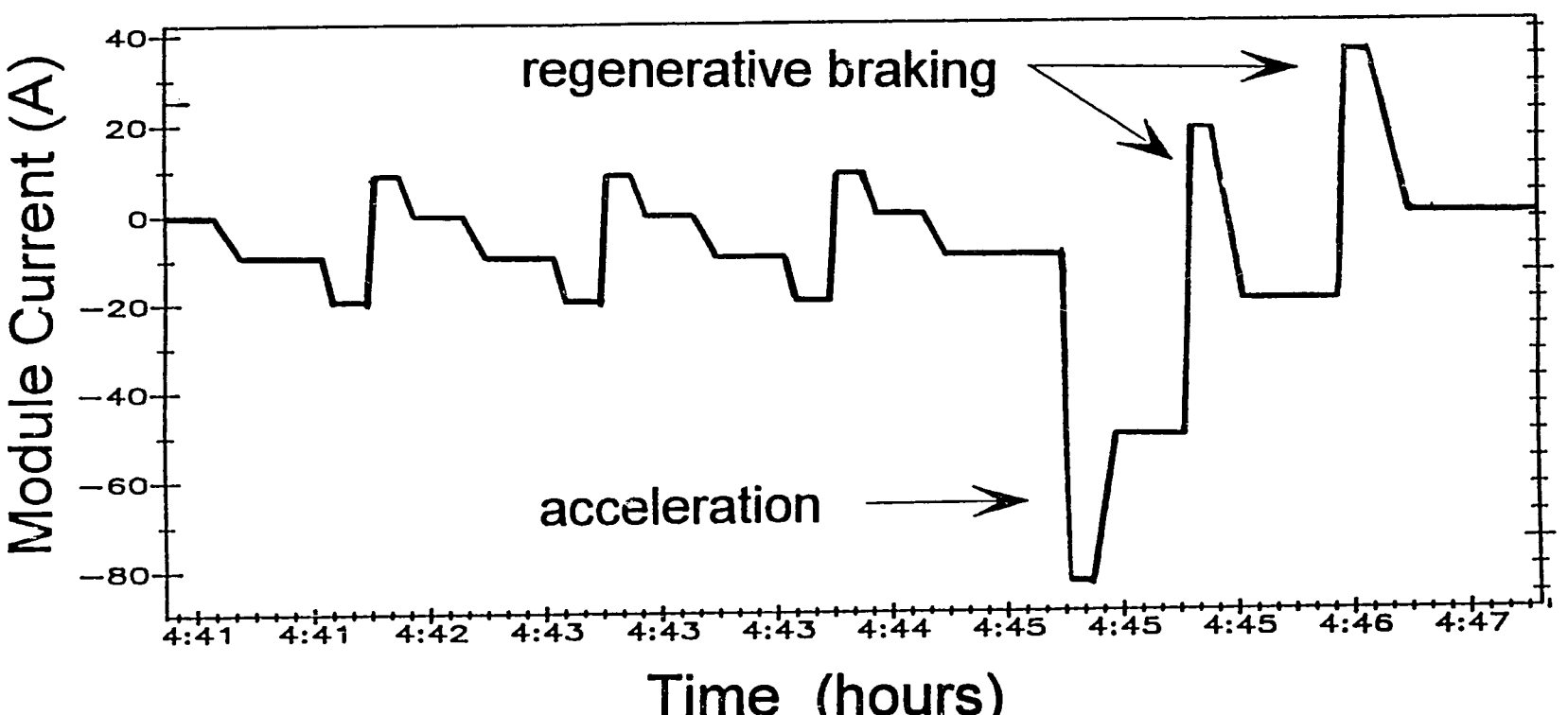


OBC 2-WHEELER BATTERY PACK

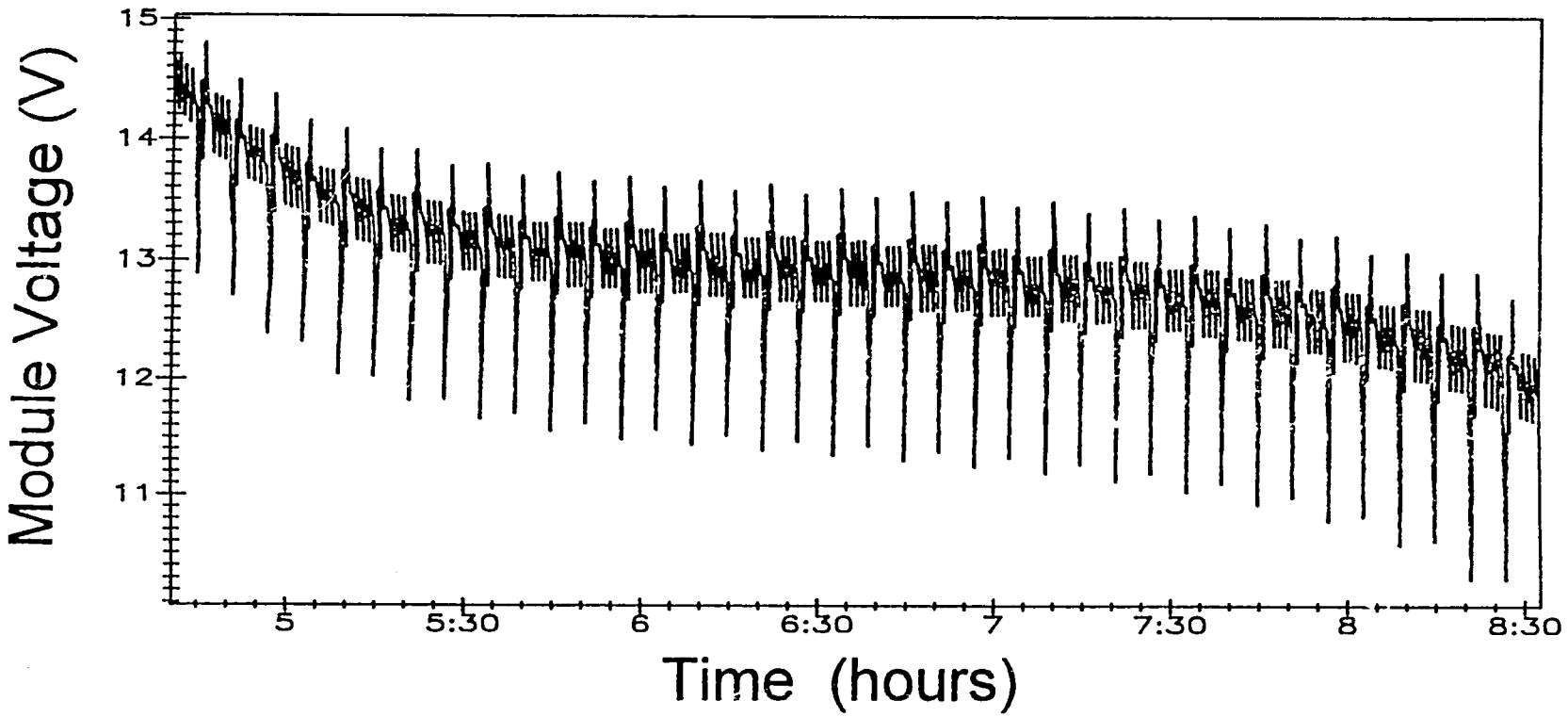
Peukert Plot of Capacity vs. Discharge Current

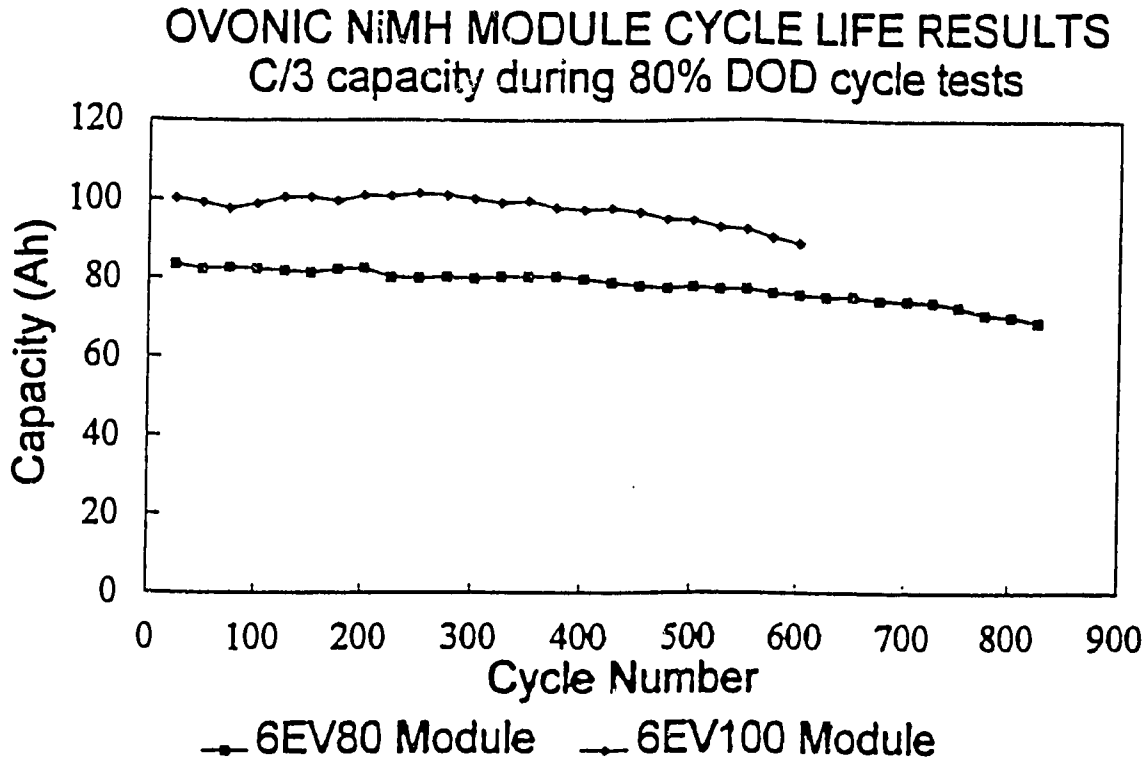


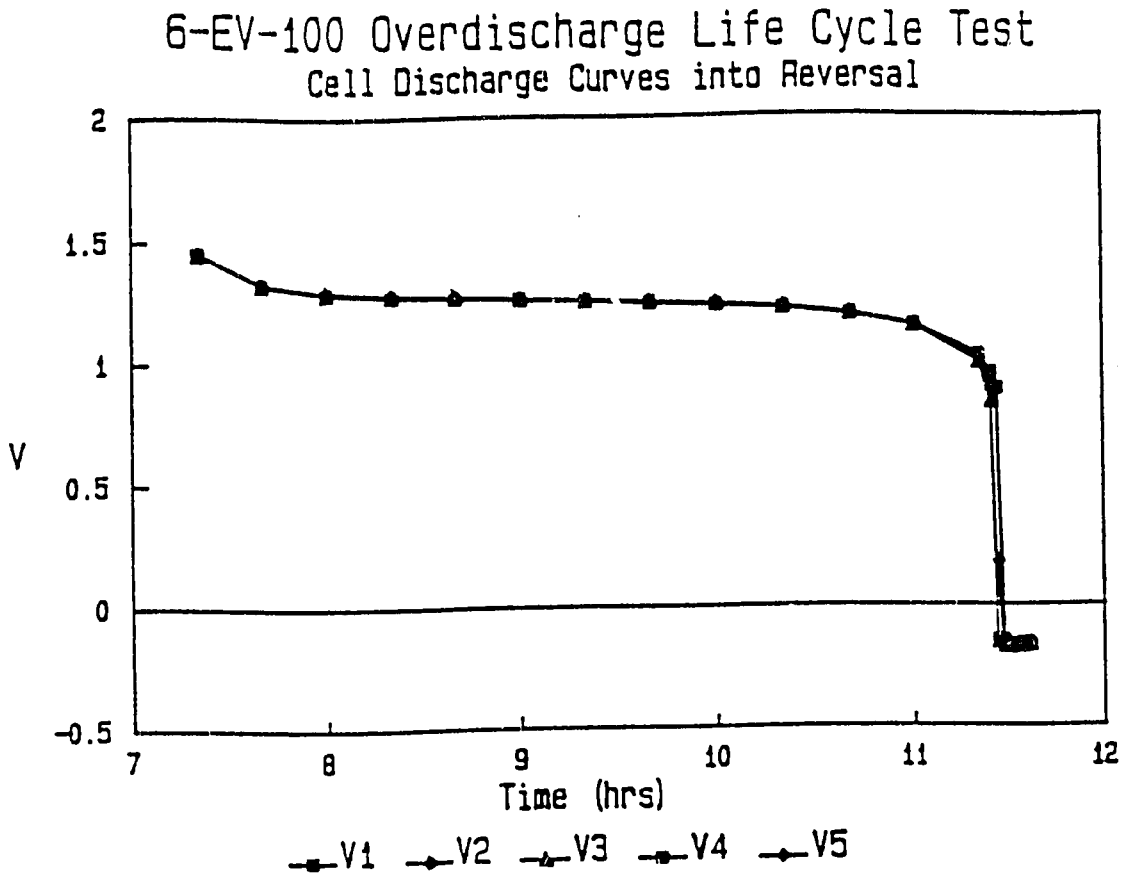
OBC 2-WHEELER BATTERY MODULE
DST Simulated Driving Cycle Discharge

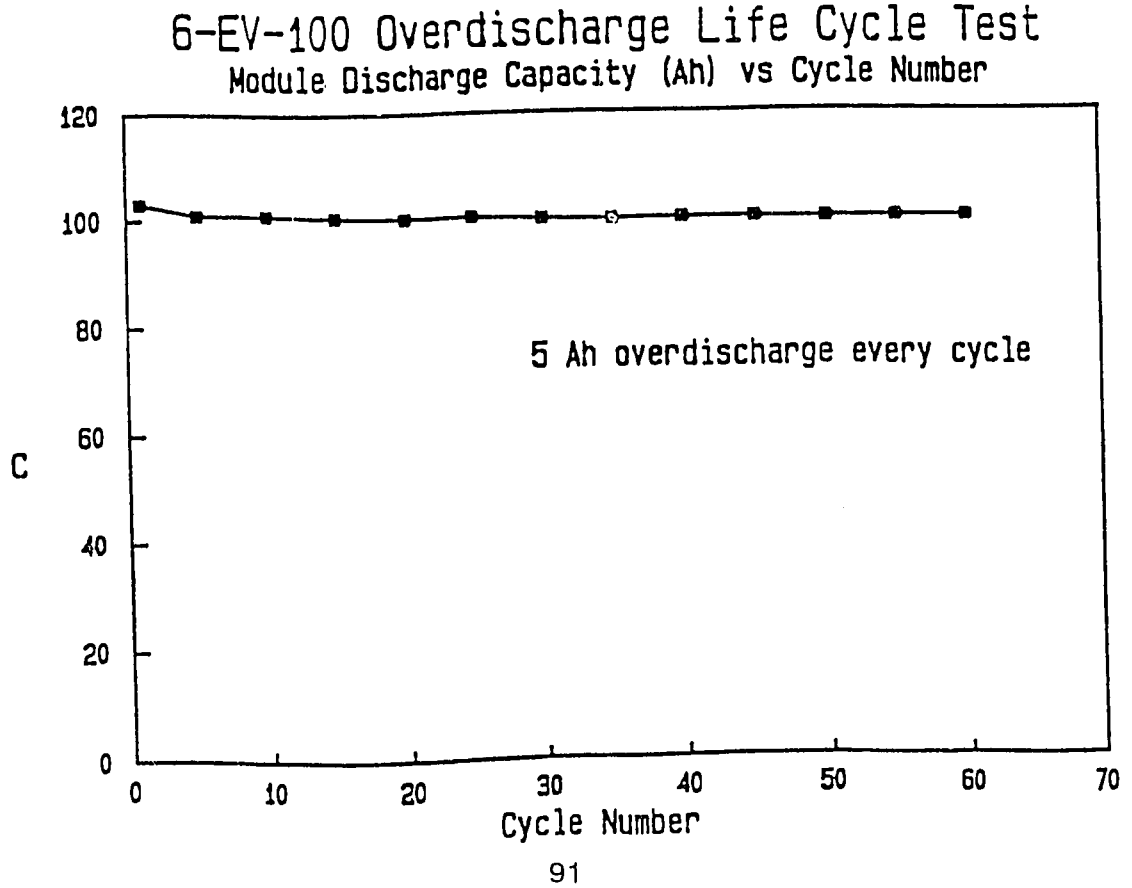


OBC 2-WHEELER BATTERY MODULE
DST Simulated Driving Cycle Discharge




OVONIC NiMH MODULE CYCLE LIFE RESULTS
C/3 capacity during 80% DOD cycle tests
Capacity (Ah)
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
Cycle Number
6EV80 Module
6EV100 Module


6-EV-100 Overdischarge Life Cycle Test
Cell Discharge Curves into Reversal
V
2
1.5
1
0.5
0
-0.5
7
8
9
10
11
12
Time (hrs)
V1
V2
V3
V4
V5


6-EV-100 Overdischarge Life Cycle Test
Module Discharge Capacity (Ah) vs Cycle Number
C
120
100
80
60
40
20
0
5 Ah overdischarge every cycle
0
10
20
30
40
50
60
70
Cycle Number

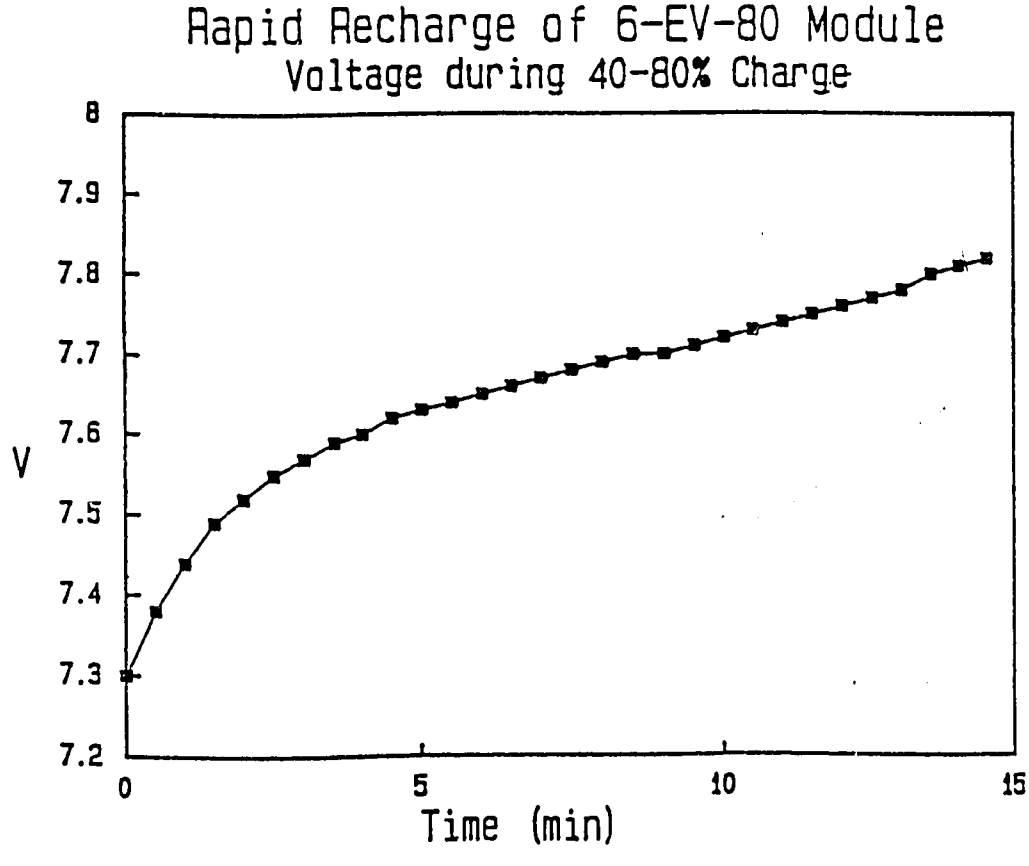
RAPID RECHARGE OF OVONIC 6-EV-80 MODULE

40 to 80% state of charge in 15 minutes meets USABC goal

charge acceptance = 100

temperature less than 45 C

pressure less than 100 psi



OVONIC NiMH BATTERY PACKS FOR 2-WHEELER ELECTRIC VEHICLES

Specific Energy	=	80 Wh/kg
Energy Density	=	200 Wh/L
Specific Power	=	250 W/kg
Power Density	=	625 W/L
Cycle Life	=	1000 Cycles
Recharge Time	=	100% in 1 Hour 50% in 15 Minutes
Operating Temperature	=	-20^0C to $+60^0$C

OBC SOLECTRIA FORCE POWERED BY OVONIC NiMH BATTERIES

Battery Pack Specifications

Nominal Voltage	144	V
Energy Capacity	19	kWh
Battery Weight	281	kg
Specific Energy	68	Wh/kg
Peak Power	45	kW
Specific Power	160	W/kg

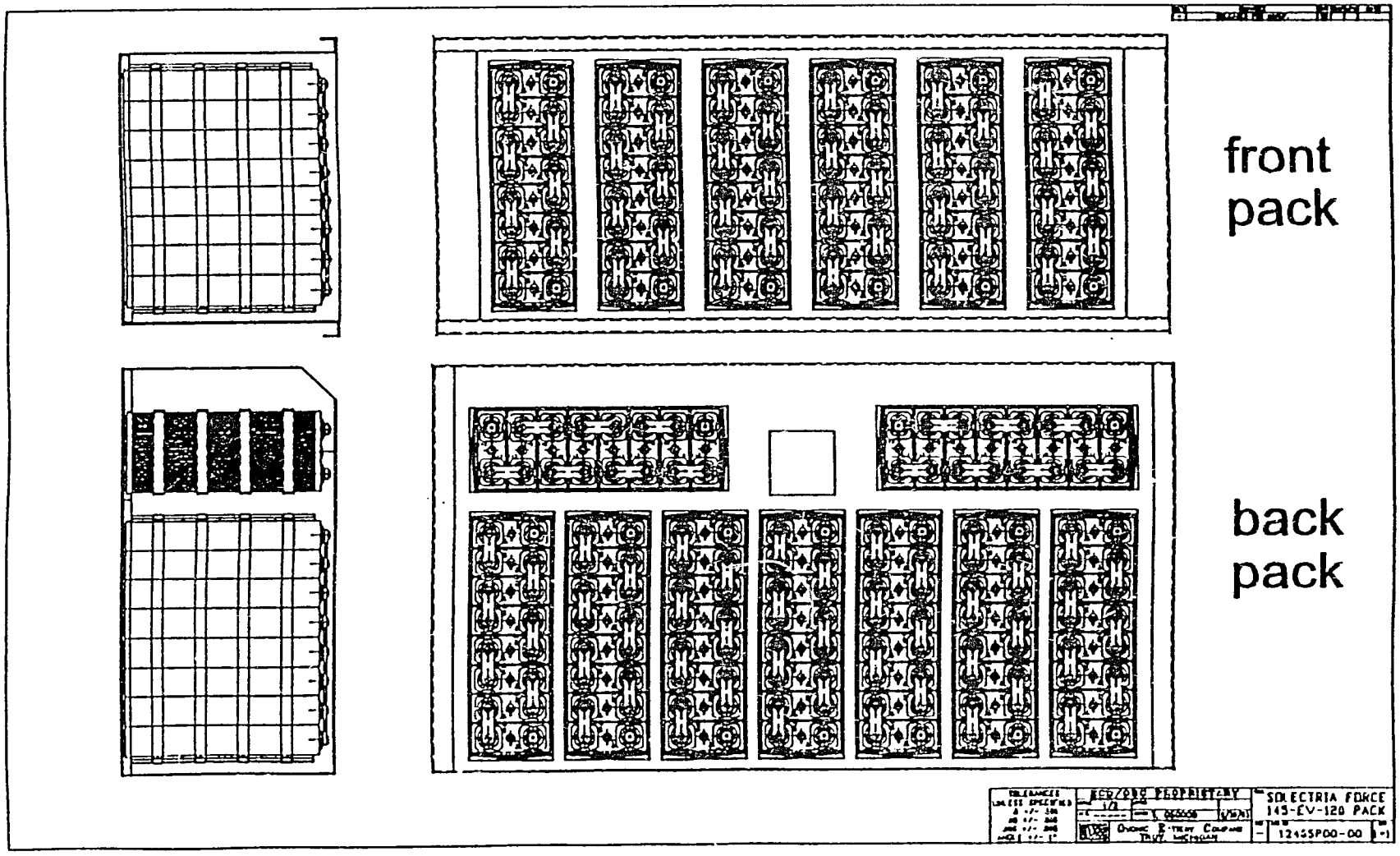
Vehicle Description

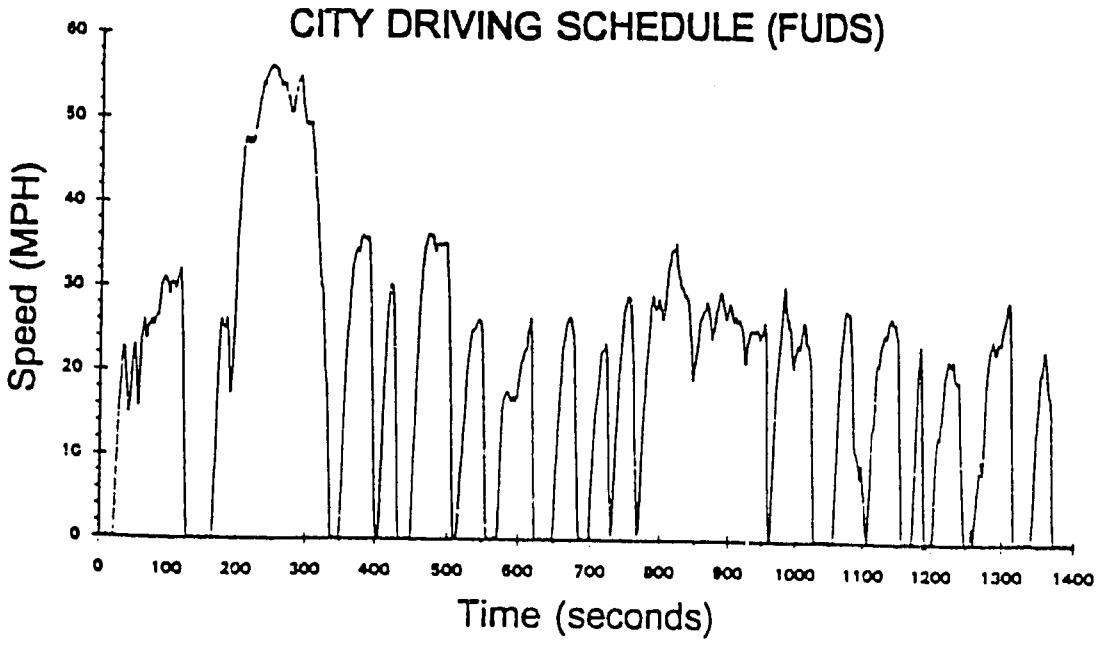
Converted Geo Metro
4 Passenger Version

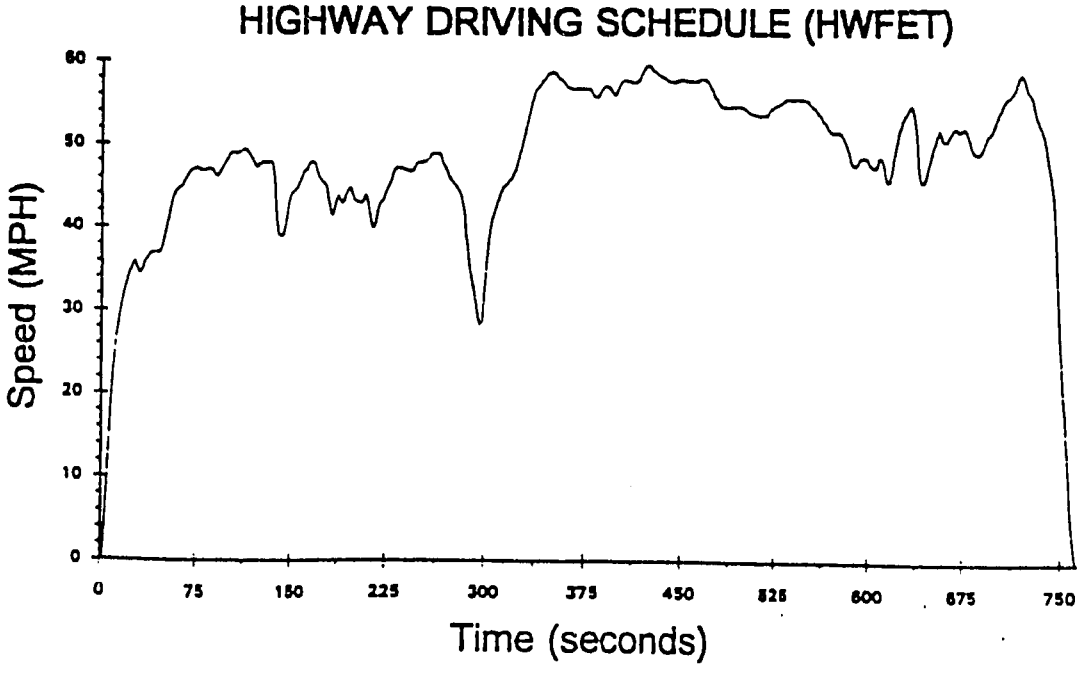
Vehicle Performance

Acceleration		
0-30 mph	6	sec
0-50 mph	14	sec
Top Speed	83	mph
50 mph Range	170	miles

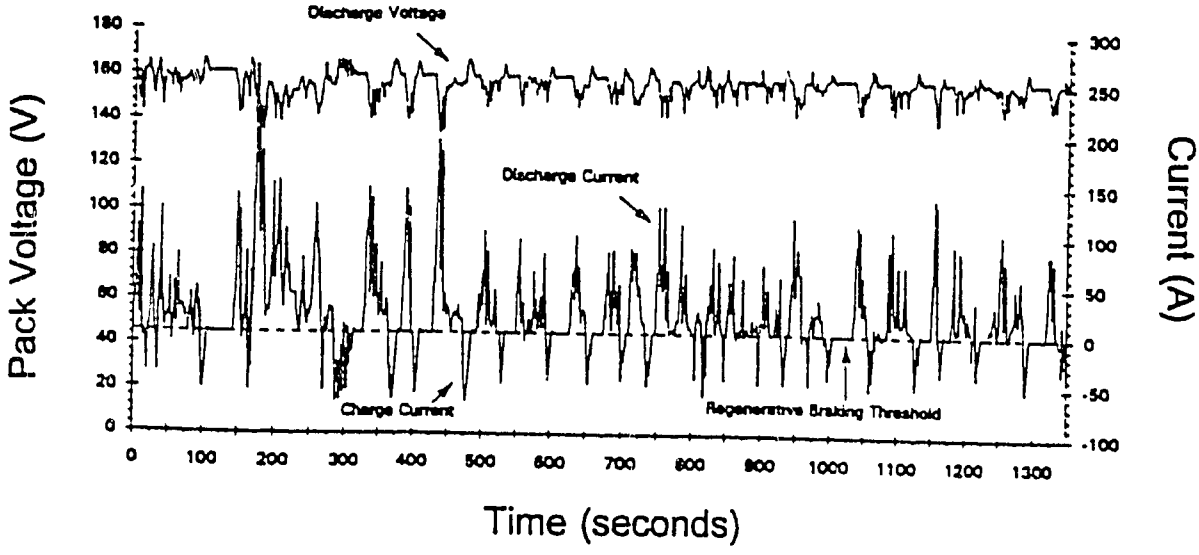
Battery Pack Configuration for OBC Solectria EV



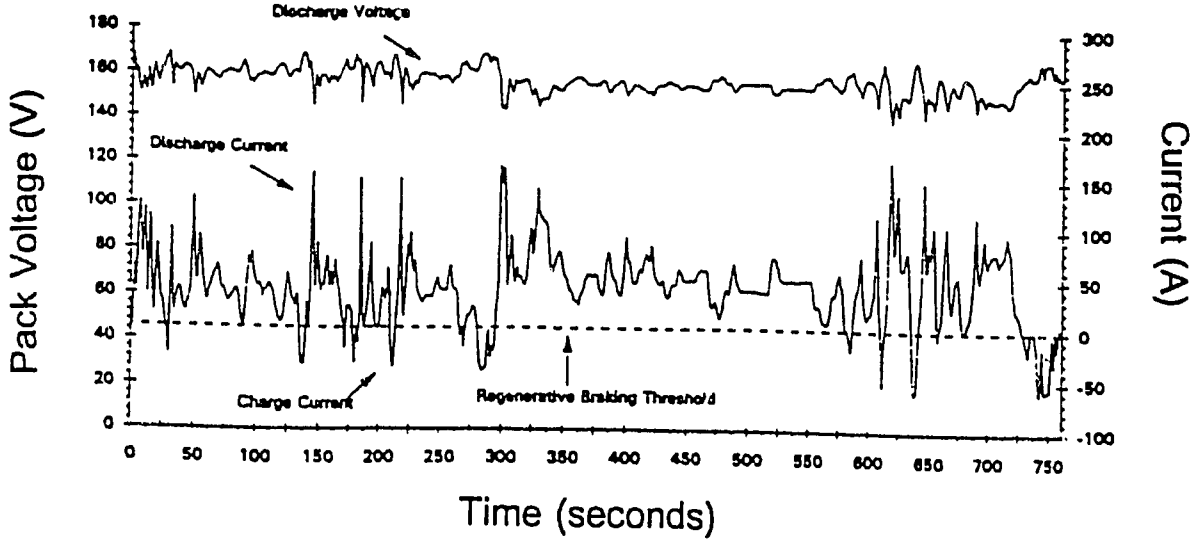

CITY DRIVING SCHEDULE (FUDS)
Speed (MPH)
Time (seconds)
0
10
20
30
40
50
60
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400


HIGHWAY DRIVING SCHEDULE (HWFET)
Speed (MPH)
Time (seconds)
0
10
20
30
40
50
60
0
75
150
225
300
375
450
525
600
675
750

OVONIC NiMH BATTERY PERFORMANCE DURING CITY DRIVING (FUDS)



OVONIC NiMH BATTERY PERFORMANCE DURING HIGHWAY DRIVING (HWFET)



VEHICLE RANGE WITH OVONIC BATTERIES

Conversion Electric Vehicle

highway range (50 mph)	170 miles
with a 15-min recharge	240 miles

Purpose-Built Electric Vehicle

highway range (55 mph)	240 miles
with a 15 min recharge	340 miles

Purpose-Built Electric Vehicle
(with next generation OBC NiMH)

highway range (55 mph)	325 miles
with a 15-min recharge	460 miles

VEHICLE DEMONSTRATIONS OF OVONIC NiMH BATTERIES

1994 Milestones

- APS 500 victory at 65 mph record speed
- Top speeds approaching 90 mph
- 0-60 mph acceleration in under 10 seconds
- 214 miles record range in Tour de Sol
- Operation at low temperatures under -20° F
- Operation at high temperatures over 105° F
- Over 60,000 total miles

Electric Vehicles and its Drive Technology in Indian Context

Mr. V. N. Walivadekar
Sr. Asstt. Director
Central Electronics Engineering Research Institute
Pilani

1.00 Introduction

The efficient, safe and pollution free transport system is, in fact, one of the main index of health of a developed society. The developing countries can no longer afford to neglect this important pollution free transport system. There has been, world over, quest for improvement in road travel safety, realization of fuel economy and minimization of air-pollution in automotive industry.

Rapid depletion of fossil fuel and global warming by tail-pipe exhausts of gasoline vehicles necessitated the development of systems for "Global warming reduction" through use of Renewable/non fossil based energy source and pollution free and noise free metropolitan city transportation.

In India, the traffic pattern is significantly different from other developed countries because of various reasons. There are narrow roads, existence of various types of vehicles, crowding of vehicles and frequent traffic junction points on the roads etc. The number of vehicles on roads is continuously rising in India (presently 20 million), which have not only resulted in increased consumption of fuel but also contributed to a large extent in increase of environmental pollution. In terms of statistics, over 60% of pollution is caused by road vehicles.

Most of it is in Metropolitan cities. Delhi, for example stated to be the fourth largest polluted city in the world. India, 2/3 wheelers and commercial vehicles are particular cause of pollution as compared to cars and to the other developed countries. In Delhi, recent study indicates that about 1000 tones of pollutants are released by the 2 million odd vehicles. It has thus become the most polluted city in India with almost 75% increase in air pollution. Statistically, Carbon Mono-oxide level is reported around 33-85 PPM in various traffic crossings in Delhi, and its intake at 30 PPM for four hours can cause dizziness and nausea, while 100 PPM can be lethal. That is to say, the need of reducing air pollution due to road vehicles, particularly the commercial ones, in a metropolitan city is very significant.

As regards fuel consumption, the requirements of fuel import by India are increasing. For example, the expected foreign exchange outflow in India during the Eight Plan on crude import is put at Rs. 36,000 crore. Similarly, the 1991 figures of total petrol consumption in India are 4 million tones. Out of this, about 25% is consumed by four wheelers. Whereas, in India, the consumption of diesel is five times that of petrol. In view of above, the development of electric vehicle system for India particularly in urban areas is of considerable relevance both in the context of reducing consumption of petrol/diesel and reducing the air pollution.

On the other hand, the significant advances in micro-electronics and power electronics alongwith the development of special electric motors paved the way for new and imaginative electric vehicle designs, although the electrically powered vehicles have stirred the imagination of vehicle designers ever since the turn of 20th century. The national and international scenario of EV development are well documented in Ref. 1.

2.00 Energy and Techno-Economic Considerations for EV

The transportation sector is the single largest consumer sector of fuel (35%) and also single largest polluting source (65%), therefore, it must be paid due attention to save energy and to reduce pollution.

Detailed study on utilization of different forms of energy used for transportation system indicates that electrical form of energy would be most efficient way of utilization of available energy (3.4 Kwh per person

per 100 KM for electric buses and trains as against 14.4 Kwh per person per 100 KM for automobiles for high wa traffic as per table 1, pp. 1, ref.2). Whereas as per ERDA report on electric-vehicles, energy consumption is between 0.34 to 0.68 whr per kilometer per kilogram for different vehicles. Battery operated vehicles by far, have shown the minimum consumption rates. In switching over from conventional internal combustion engines to electric vehicles, the other main consideration is the efficiency of utilization of available energy. Various studies have been made and are continuously being carried out on these aspects, particularly crude oil or coal as the primary sources of energy, which are available at present. The overall efficiency of utilization in case of battery powered vehicle is 14.4% as compared to 14.2% that of petrol engine (Ref. 3). Mayer (Ref.3) has also mentioned that the drive train efficiency of electric-vehicle is 50% as against 18% that of IC engine. The other benefits of electric-vehicle is low maintenance, reduction in audible noise & pollution in urban environment and possibility of use of non-conventional energy sources thereby change in pattern of use of energy source.

Since city transport has higher kilometer run/day as compared to intercity transport, it consumes major portion of gasoline imported as well as pollutes maximum. Secondly, in Indian cities, where the road capacity and speeds are low and distance travelled do not exceed 50-60 KM, electric vehicle (EV) seems to be the most lucrative solution to replace the gasoline based city vehicles.

The Indian city transport consists of varied type of vehicles such as 2/3 wheelers, cars, tempos, diesel based mini buses and buses, delivery vans etc. If the pollution is the main criteria for replacement then 2/3 wheelers are to be given higher priority for replacement as they pollute more and also large in numbers. But the absolute subsidy to be provided for compensating the high initial cost so as to promote EV is high thus burdens government. When energy and its efficient utilization is the main consideration, then higher capacity vehicles mostly operating on diesel, are to be given higher priority because the consumption of diesel is five times that of petrol and diesel vehicles pollute more than petrol vehicles. Secondly, it is relatively easy to implement the replacement as they are mostly owned by Government/Semi Government and absolute subsidy is also low.

An in-house exercise based on the available data was carried out for economic comparison of 2/3 wheelers electric and petrol vehicles. The details are given in Table-I. The conclusions are:

a. The initial cost of electric vehicle is higher than petrol vehicle. If a 20% subsidy is provided to promote EV then the initial cost is at par with the petrol vehicle.

b. The life of the EV is 20 years and that of petrol vehicle is 7 years but for comparison, it is taken as 12 years and 10 years respectively.

c. The operating cost of EV is about 20% that of petrol vehicle due to low maintenance and utility as the energy source to recharge the batteries.

d. The cost per KM per passenger for EV is about 35% that of petrol vehicle.

The techno-economic comparison of different capacity electric vehicles are shown in Table II and Table III. The conclusions are :

a. The cost per Km and energy/Km are higher for vehicles having higher GVW.

b. The range and cost per Km per passenger are directly proportional to the ratio of pay-load to battery weight.

3.00 Electric Automotive System

The battery operated electric vehicle is defined as a vehicle with portable energy source of electro-chemical nature whose traction effort is supplied by an elecric motor. Fig. 1 shows the essential components of the drive-train of an EV as per the above definition. The power source, which is electro-chemical in nature, is generally a battery source and drives the electric motor through a power controller which converts the dc battery voltage to dc voltage of different level or ac voltage depending on the type of motor which drives the vehicle.

Design of an EV calls for innovative approach, wholly different from well established design procedures of the conventional IC engine vehicles as the EV gets its energy from the battery whose energy density and volumetric density are much less compared to the other conventional energy sources (Energy density of 12,300 Wh/Kg for Gasoline as against 150-300 Wh/Kg for Sodium-Sulphur batteries as per Table 3.1, on pp. 52 of Ref. 4).

a. A constant torque zone up to the base speed to overcome the inertial force and to provide tractive-efforts for accelerating up to the desired speed.

b. A constant horse power zone after the base speed to overcome the running road load loss at the desired speed.

c. Regenerative braking to feed back the energy stored in the wheels back to the power source.

In conventional mechanical braking, the kinetic energy of the vehicle is dissipated as heat in the brakes, thus wasting the energy stored in the vehicle and causing wear and tear to the brake shoes etc. which results in extra maintenance cost and time. This disadvantage is eliminated in electric vehicle using electric motor with the help of dynamic and regenerative braking. In dynamic braking the electrical energy generated by the drive operating as generator is dissipated across resistors. While in the case of regenerative braking, the electric energy generated during braking is used to charge the battery of the electric vehicle.

The drive technology, in addition to battery technology, is another key factor affecting the range and performance of the electric vehicle. With growing interests in electric-vehicles, much effort is demanded for the development of efficient, reliable and economical drives for EV propulsion purpose. Presently there are four alternatives for the EV drives. They are DC Motor (DCM) drive, Induction Motor (IM) drive, Switched Reluctance Motor (SRM) drive and Brushless DC Motor (BDCM) drive. The DC Motor drive is well established and has been in use since long whereas Induction Motor drive is now being employed. Brushless DC Motor drive has found its application in low power range and Switched Reluctance Motor Drive has been recently proposed as potential drive for electric vehicle.

Fig. 3 shows the family tree of electric motors (Ref. 5). While conventional motors still dominate over other motors. A major revolution in motor technology matching with the advances in power electronics in recent past would certainly cater tothe transportation sector's needs for high performance, simple and cheaper drives. It, then will become difficult to separate motor from electronics as they would work together as a single integrated functional element of a total system. In the motor family tree shown in Fig. 3, DC series motor acted always as the traction motor till recent past due to its inherent torque-speed characteristics which almost matches with the required torque-characteristics of traction. (For details please see Ref. 6 and 7). Combined with suitable power electronic circuits, the variable frequency AC induction motor, Switched Reluctance Motor and Brushless DC Motor are the main competitors to the traditional dc series motor. For details on IM Drive, please see Ref. 6 and 7, for SRM Drive, Ref. 8 and 9 for BDCM Drive Ref. 8 and 10.

Main criteria for selection of Drives for EV, are cost, reliability, efficiency, maintenance, durability, weight, size and noise level. Eventhough dc motor drives have been used in near-term commercial EV's, they will finally be replaced by AC motor drives mainly due to DC motor's low reliability, low efficiency, high operating cost, bulky size, heavy weight and speed limitation. SRM drive as compared to DCM & IM Drives is simple, cheap, robust and requries minimum maintenance. It has inherent torque-speed due to unidirectional current requirements and has inherent shoot-through protection apart from efficient operation over a wide range of power and speed. But it suffers from torque ripple and noise. The detailed comparison of DCM, IM and SRM is provided in Ref. 9 whereas tabulated comparison of IM, BDCM and SRM drives is provided in Ref. 10.

On the basis of the opinion of experts collected by Dr. Chang L. (Ref. 11), the relative comparison of IM, BDCM and SRM Drives are summarised below :

a. IMs have low efficiency, high reliability, low power density, low torque ripple, high overload capacity, large size, low cost and medium maximum speed. IM converters have low efficiency, medium/high control complexity, low power density and high cost.

b. SRMs have medium/low efficiency, medium reliability, medium power density, high torque ripple, medium/low overload capacity, medium/low size, medium cost and high maximum speed. SRM converters have medium efficiency, low control complexity, medium power density and low/medium cost.

c. BDCMs have high efficiency, low reliability, high power density, small size, high cost and low maximum speed. BDCM converters have high efficiency, high/medium control complexity, high power density and medium/low cost.

d. The sizes of IM, SRM and BDCM converters are similar. In brief, according to survey (Ref. 11), induction motor drives are best suited for EV propulsion purpose, due to their low cost, high reliability, high speed, established converter and manufacturing technology, low torque ripple/noise and absence of position sensors. BDCM drives feature compactness, low weight, high efficiency at high cost and low maximum power rating at present. SRM drives with their low cost, compact size and reliability may provide an alternative for EV drives.

4.00 Role of CEERI in Promoting Electric Vehicle Development in India

The development of Electric-Vehicle is highly multidisplinary. It consists of vehicle design, battery development and Electric Drive Development. CEERI, being pioneer in Electronics, initiated a programme on "Electric Drive" for Electric Vehicle in a phased manner anticipating the relevance of Electric Vehicle system in Indian context (60% of pollution in Indian metropolitan cities is caused by road vehicle and one fourth of total petrol consumption in India is of four wheelers) and considering CEERI's strength in Power Electronic and AC Drives. The phases are (1) Feasibility of converting the present petrol vehicle into an electric vehicle (retrofitting) and (2) An optimised electric vehicle.

While Electric Vehicles developed so far in the country run on a DC driven motor that has several shortcomings such as heavy maintenance due to wear and tear of contactors, switch gears, commutators and brushes. CEERI, Pilani concentrated its efforts on Induction Motor based Electric Vehicle drive-train since Induction Motor requires minimum maintenance due to absence of commutator and brushes, is lighter and more compact and has higher efficiency. With the availability of high power transistor and well established inverter technology, the Pulse Width Modulated (PWM) Transistorized Drive has become an unanimous choice for the CEERI's Electric Vehicle.

4.01 Technology

EV, being "Energy Short" Vehicle, calls for innovative design approach. It requires to maximise the energy efficiency in the drive-train from battery to wheels on one hand and to reduce the energy loss on the other hand and thus calls for an integrated design approach. The basic induction motor drive as shown in Fig. 1 consists of an Induction Motor and power controller. The power controller is made up of a 3-phase transistorised pulse width modulated (PWM) inverter whose output frequency and voltage can be continuously varied. The output of the inverter feeds a 3-phase squirrel cage induction motor. In order to utilize the motor magnetic properties to the maximum extent the flux in the motor by imbedding flux sensing coils in the stator slots. The drive has a constant torque capability upto base speed and beyond base speed, the drive operates in constant power mode. The constant power mode is suitable for cruising beyond the base speed. The torque speed characteristics of the drive meets with that of the load as shown in Figure 2.

The inverter operates from 120 V battery bank. The inverter is made up of bipolar power darlington switches. The inverter is a pulse width modulated type with a frequency index of 30. This enables the motor

current to be smooth with small ripple. This feature results in reduced ripple current thus enhancing the overload capacity of the electric vehicle. The inverter is short circuit protected. This is accomplished by sensing the current in the dc link and removing the pulses to the power switching devices in the event the current exceeds a present value. The minimum operating frequency is 6 Hz for the drive. Type of modulation scheme employed is sinusodial pulse width modulation in which a set of three phase sinusodial voltages are compared with a common triangle carrier.

4.02 Implementation

During first phase, an "Electric Power Controller" consisting of a three phase transistorized PWM inverter whose output frequency and voltage can be varied, was developed, bench tested and tailored to the requirement of an electric vehicle. The feasibility of retrofitting of induction motor drive was first studied on an old ambassador car to understand the requirements of inverter, battery, driver panel, interface between inverter and driver's command, and to study the effect of weight, energy density etc. of battery.

The vehicle selected for experimentation was expected to have Gross Vehicle Weight of 1500 Kg and had differential gear ratio of 3:1. As per preliminary calculations, the estimated torque required for accelerate upto 30 KMPH speed is about 10KW. This corresponds to a motor speed of 900 rpm. Fig. 4 shows the torque and power requirement an ideal driving cycle. The following work was carried out :

i. The vehicle weight was reduced by 250 Kg after removing unwanted parts such as petrol engine, gear box, radiator and petrol tank.

ii. The available 15 KW induction motor drive, developed by CEERI and pulley for coupling motor to propulsion shaft were mounted in ambassador car.

iii. A battery bank of 120 V, 100 AH made available by CECRI, Karaikudi were placed in the vehicle.

iv. The induction motor drive was first bench tested for required vehicle characteristic.

v. The tests were conducted and vehicle was run in the following steps:

   a. Rectified mains and IM controller outside vehicle and induction motor inside ambassador car.

   b. Battery bank and IM controller outside vehicle and induction motor inside ambassador.

   c. Battery bank outside vehicle and complete drive inside ambassador car.

   d. Battery bank outside vehicle and complete drive inside ambassador car with 6 persons inside.

The results of investigation are as follows :

i. The weight or GVW is one of the important factors responsible for the vehicle performance. It must be reduced as much as possible.

ii. Battery weight should be properly distributed on four wheels from the safety consideration.

iii. Battery container should be light, shock, vibration and accident proof.

iv. Battery should have high specific energy and power to supply high starting current and continuous current.

v. The vehicle should have sufficient space to conduct tests/measurements during experimentation.

vi. The controller should be tailored to the needs of electric vehicle and should be robust & reliable to meet the road worthiness specifications.

vii. Vehicle needs a "Master Controller" to sequence the operation, to interface driver's command to the controller and to interlocking operation to avoid accident and malfunctioning.

After analysing the results obtained from the field-trial of retrofitting in Ambassador Car, it was subsequently decided to convert a jeep into a prototype laboratory model by installing a squirrel cage induction motor, an inverter based electronic controller unit, a driving mechanism, 120 V battery bank and driver's interface. As a follow-up action, a jeep body having sufficient space to conduct experiments was procured and modified to retrofit the Induction Motor drive. A compact and light weight IM controller was redesigned. A master controller and light weight and compact high frequency dc to dc conversion based power supplies were incorporated.

CEERI tested the country's first C (Induction) motor driven electric vehicle in March 1994 that can cater to short local trips without polluting the environment. The eight seater two tonne vehicle is expected to run about 70 KM per charge, which makes it ideal for short local trips to schools, airports or railway stations. Having no gears and clutches, it is simple to drive and expected to attain a cruise speed of 40 KMPH and maximum speed of 60 KMPH. The running cost is estimated to be 28 paise per passenger-km including the cost of battery and total cost to 43 paise per passenger-km compared to normal petrol driven vehicles whose running cost is 49 paise per km per passenger. The recharging of battery, at present, takes six hours and cost only Rs. 36.

5.00 Conclusion

The recent thrust on pollution reduction and energy saving and shift towards the use of non-conventional energy source on one hand and recent development of electric vehicle having improved performance due to advances in electronic drive technology on the other shall make the Electric Vehicle techno-economically viable for urban traffic conditions prevailing in India. In comparison to Petrol Vehicle, EV has low operating costs and high initial costs due to limited production at initial stages, which can be compensated by providing subsidy to promote EV.

DC motor drive is going to be replaced by Induction Motor Drive in near future. IM Drive is best suited for EV propulsion system amongst IM, SRM & BDCM Drives at present. SRM drive is expected to be the variable speed drive of the future.

Central Electronics Engineering Research Institute (CEERI), Pilani, first time in India demonstrated the feasibility of AC (Induction Motor) driven electric vehicle. CEERI foresees, a good prospects of EV in urban India.

6.00 Acknowledgement

The author expresses his deep sense of gratitude to Professor Biswas, Director, CEERI for his valuable suggestion and continuous encouragement. He gratefully acknowledges the helpful comments and suggestions from Sh. R.S. Mahajan, Group Leader during manuscript preparation. He is also grateful to EV Project team members Dr. H.V.Manjunath, V.Sarat Babu, Kamal Saddar, Sushil Kr. Saini, D.D. Joshi and O.P. Sharma for their whole hearted and sincere support.

The author is also thankful to Mr. Lalit Khanna for his timely help in preparing manuscript of the paper.

7.00 References

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Table - I

Comparison of Electric and Petrol Vehicle

S. No.	Parameters	Two Wheeler (2)		Three Wheeler (4)	
		Electric	Petrol	Electric	Petrol
1.	Seating capacity	2	2	4	4
2.	Ex-work cost	45,126	-	90,930	-
3.	Net Cost = ED + ST + subsidy	40,162 ED = 5.75% ST = 3% Subsidy=20%	20,000	80,928 ED = 5.75% ST = 3.00% Subsidy=20%	40,000
4.	Net fixed cost Less depreciation Salvage value and add interest	39,088 Depreciation -100%, 42% Salvage-10% Int. 12%, 5 year on 75%	33,400 D = 33.3% S = 10% Int.=21%, 5 years	78,764 Depre.-100% 42% S = 10% Int. on 75% @ 12% for 5 years	66,800 D = 33.3%, 28% S = 10% Int. = 21%, 5 years
5.	Fixed cost/year	3258 (Life = 12 years)	3340 (Life = 10 years)	6564 (Life = 12 years)	6680 (Life = 10 years)
6.	Yearly Run (Km) 60 Km/day 330 days/year	19,800	19,800	19,800	19,800
7.	Energy/year (KW)	277.2	495 ltr. @ 40 Km/hr	537.37	1100 ltr. @ 18 Km/hr.
8.	Energy cost/year	Rs. 555 @ Rs. 2/Kw	Rs. 9,900 @ Rs. 20/ltr	Rs. 1075 @ Rs. 2/Kw	Rs. 22,000 @ Rs. 20/ltr.
9.	Battery replace-ment cost per year (Rs. 2/- per hr.)	1680 (Life = 3 years)	100	3600 (Life = 3 years)	200
10.	Maintenance cost per year	782 (EV = 2% of net fixed cost)	1670 (5% of net fixed cost)	1575 (EV=2% net fixed cost)	3340 (5% of net fixed cost)
11.	Operating cost/year (8+9+10)	3017	11,670	6250	25,540
12.	Total cost/year (5+11)	6275	15,010	12,814	32,220
13.	Cost/Km	0.32	0.76	0.65	1.63
14.	Cost/Km/passenger	0.16	0.38	0.16	0.41

Table - II

Comparison of different capacity EVs

Sl. No.	Seating capacity	Scooter 2W 2 seater	3 W 4 seater	Van 1+5=6	Jeep 8	Minibus 18	Bus 40
1.	Pay load Kg @ 70 Kg/person + Luggage 20 Kg/person	150	350	550	700	1250	2800
2.	Max. speed (KMPH)	60	40	60	60	50	50
3.	Cruise speed (KMPH)	40	30	40	40	40	40
4.	Acceleration ($m.sec^2$)	0.4	0.4	0.4	0.4	0.4	0.4
5.	Gradient (%)	10	10	10	10	10	10
6.	Battery capacity (whr) V AH energy whr	48 V 35 AH 1680	72 V 50 AH 3600	120 V 65 AH 7800	120 V 100 AH 12000	96 V 300 AH 28800	160 V 300 AH 48000
7.	GVW (Kg)	330	710	1500	2000	4000	7500
8.	Power rating of motor with gear = .95 and 200% overload for few seconds (Kwatts)	1.100	1.75	5.40	7.20	15.60	29.00
9.	Inverter rating with gear =.0, = .95 pf=0.8 (KVA)	3.05	4.80	15.0	20.0	43.20	81.00
10.	Energy/Km at cruise speed at battery nv = 0.95 n total = 0.81	14	27	89	119	308	574
11.	Range at cruise speed (Km)	96	106	70	80	75	70
12.	Total cost/Km (Rs)	0.32	0.65	1.72	2.27	4.30	7.17
13.	Cost/Km/Passenger (Rs)	0.16	0.16	0.29	0.29	0.24	0.18

Table - II

Comparison of different capacity EVs

Sl. No.	Seating capacity	Scooter 2W	3 W	Van 1+5=6	Jeep 8	Mini bus 18	Bus 40
1.	Ex-works cost (Rs)	45,126	90,930	2,53,680	3,14,160	4,91,640	7,95,180
2.	Net cost (Rs)	40,162	80,928	2,25,775	2,79,603	4,37,560	7,07,710
3.	Net fixed cost (Rs)	39,088	78,764	2,19,738	2,72,126	4,25,859	6,88,785
4.	Fixed cost/year for a life of 12 years (Rs)	3,258	6,564	18,312	22,667	35,488	57,399
5.	Operating cost/years (Rs)	3,017	6,250	15,725	22,152	49,154	84,506
6.	Total cost/year (Rs) (4+5)	6,275	12,814	34,037	44,829	85,002	1,41,305
7.	Cost/Km (Rs)	0.32	0.65	1.72	2.27	4.30	7.17
8.	Cost/Km/ Passenger (Rs)	0.16	0.16	0.29	0.29	0.24	0.18
9.	Range (Km)	96	106	70	80	75	70

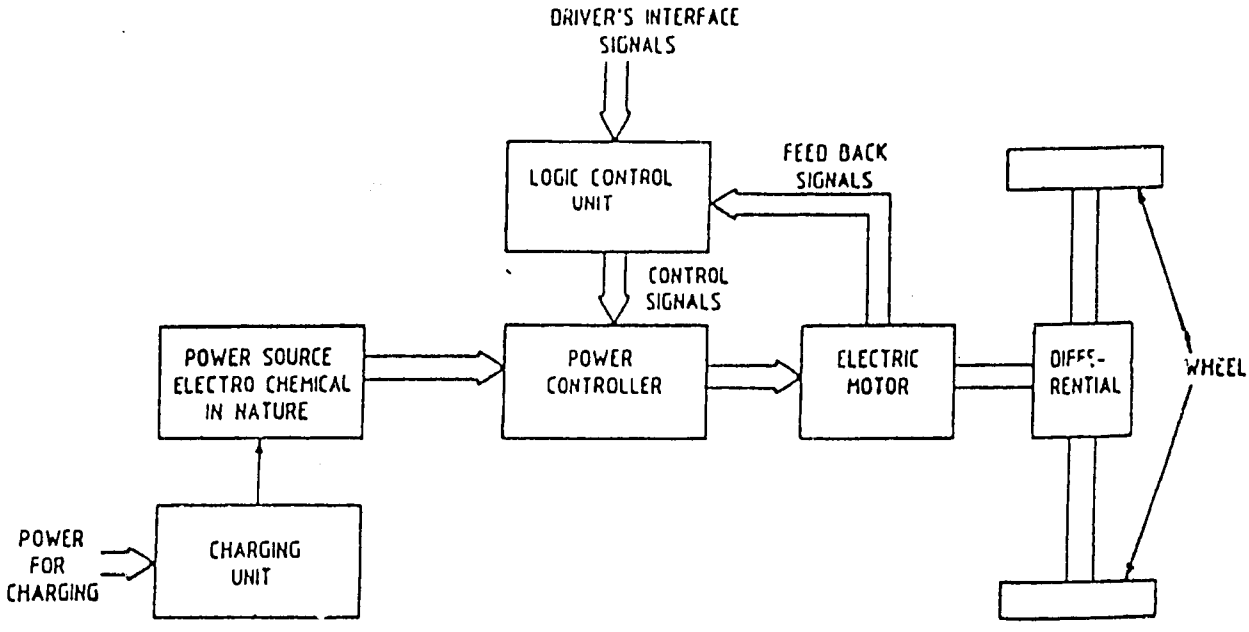

Fig. 1 Principal components of the electric vehicle drive train

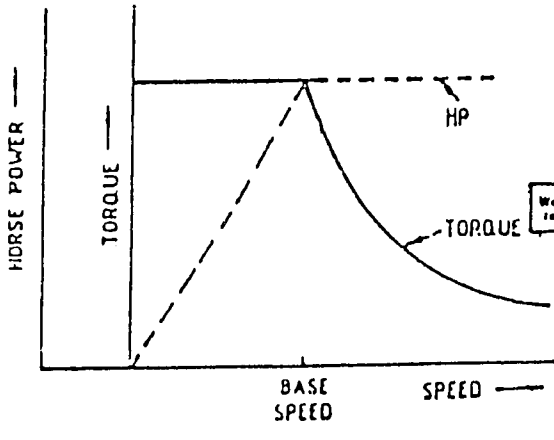

Fig. 2 Required Torque/HP-speed characteristics

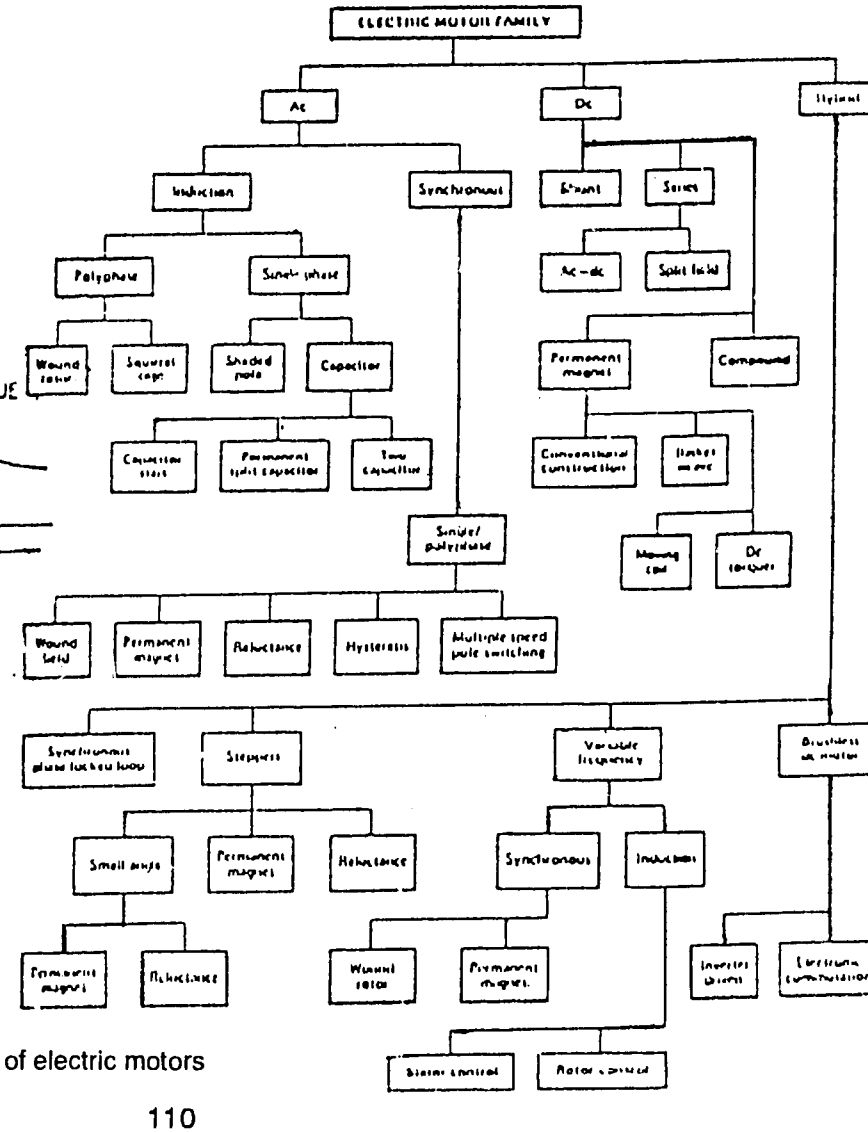

Fig. 3 Family tree of electric motors

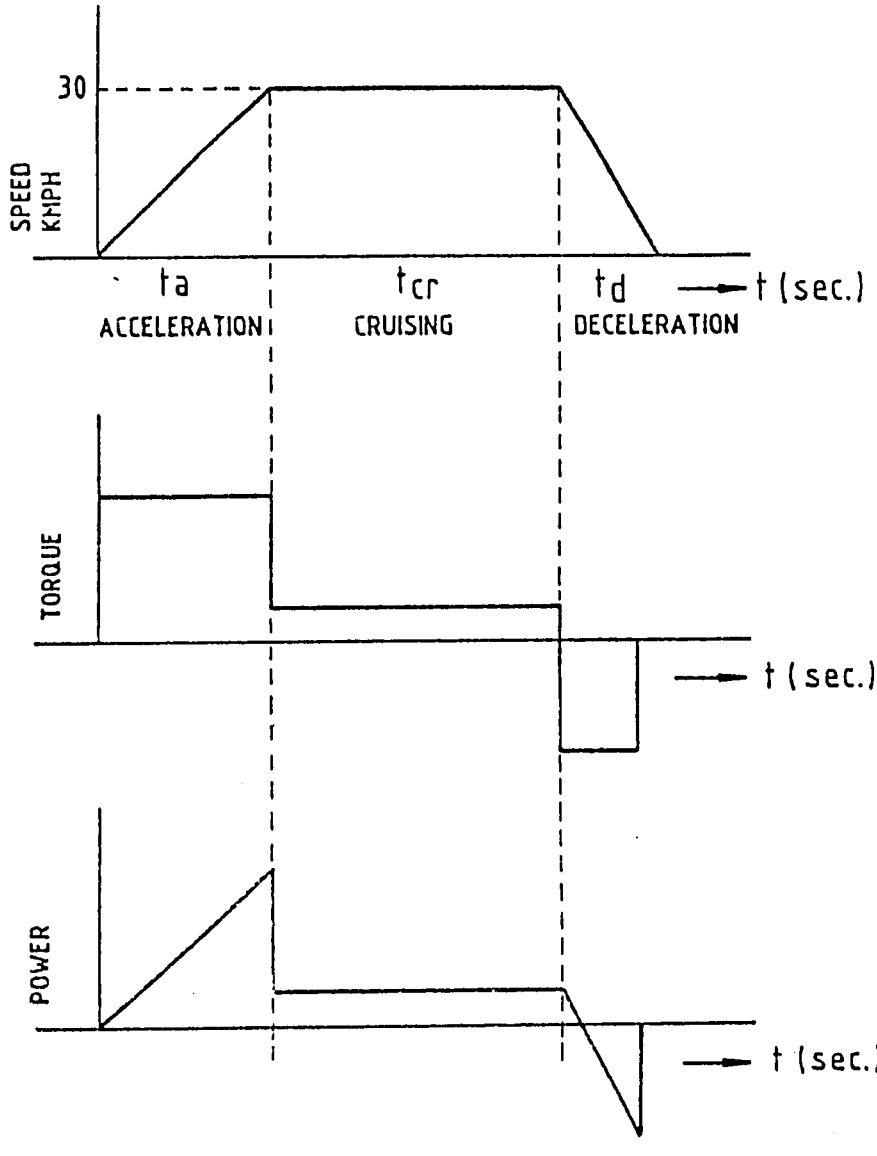

Fig. 4 Typical Driving Cycle in an Electric Vehicle

Electronic/Electric Vehicle Drive Development

Mr. M.D. Jos
Managing Director
and
Mr. Biju Abraham Mathew
Dy. General Manager
Eddy Current Controls (I) Ltd.
Coimbatore

This paper speaks about the drive development for Eddy's Electric Car "Love Bird". Love Bird is a cute two seater Electric Car developed by Eddy Current Controls (India) Limited, the Company which gave momentum to the Electric Car development programme by its pioneering efforts. The author explains the present drive system consisting of a dc series motor and chopper controller and goes on to add the Company's programme for the development of a switched reluctance drive as an alternate drive system.

LOVE BIRD is a small, cute two seater car developed by M/s Eddy Current Controls (India) Ltd. Eddy has been a pioneer in India in the manufacture of various high tehnology products like Veriable Speed Eddy current drives, Microwave ovens, etc. Eddy's long experience in variable speed drives has been helpful in the development of Electric vehicle drive.

The Drive and Power System

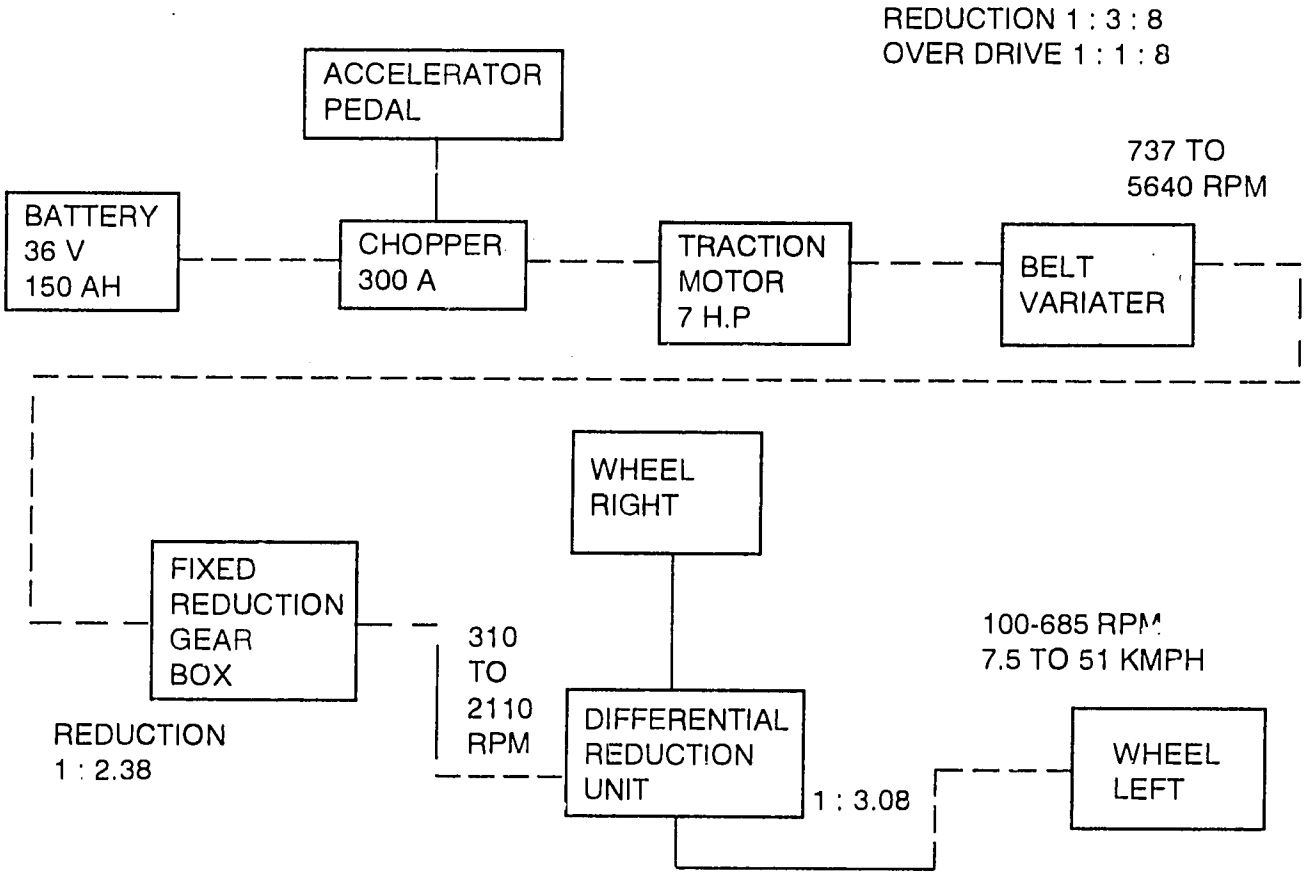

Fig. 1 illustrates the drive and power system of the present version of "Love Bird". The source of power is a 36 volt, 150 AH lead acid battery pack. Power is transmitted to the wheels by a 6HP DC series Motor, followed by a mechanical variator and a reduction gear box, the transmission shaft and differential as seen from the figure. Smooth speed control is achieved by a MOSFET Chopper cotroller, which controls the motor speed based on the position of the accelerator pedal.

Electric Vehicle drive demands the following characteristics:

i. High starting torque.

ii. High efficiency over a wide range of speed and power.

iii. Robustness and less maintanance.

iv. Light weight and compactness.

A DC Series Motor was chosen to power Love Bird as it delivers a high starting torque.

Chopper control was developed for smooth speed control (The first control was a thyristor chopper which was recently replaced by a MOSFET chopper controller).

Fig. 2 Principle of Chopper

Fig.2 illustrates the principle of operation of chopper controller. The speed of a DC Motor is directly proportional to the voltage applied to the Motor armature.

$$N \times Vm/O$$

Where Vm is the voltage across the armature and O is the flux. For a constant flux, N is directly proportional to Vm.

A chopper is nothing but a high speed semi conductor power switch, which controls the voltage applied to the Motor by ON-OFF duty cycle control.

The MOSFET chopper is simple, reliable and free from commutation problems unlike in thyristor controllers. It is compact, and totally enclosed and is priced low compared to thyristor chopper and Induction Motor controller.

Switched Reluctance Drive - An Alternative Drive System for Electric Car

Though the DC Series Motor gives good performance on LOVE BIRD, the SR machine is expected to deliver better result in terms of efficiency and thus increasing the range of the vehicle.

The SR Machine is a brushless DC Machine. Fig.5 illustrates the construction of an SR Motor.

A typical SR Motor consists of an 8 pole stator and a six pole rotor. Each stator pole pair is fitted with a coil to form 4 phases. The rotor is a pressed stack of stampings, as shown in the figure. Energising a diametrically opposed pair of stator coils pulls a pair of rotor poles in to line. This causes the rotor to revolve smoothly when supplied with sequential controlled pulses. Optical/hall wear free sensors provide rotor position, direction and speed data to the controller. The control system provides accurately timed current pulses enabling just sufficient power to maintain the required speed and torque, providing a system with high efficiency maintained over the entire speed and torque control range.

Requirements of Traction Drives

* High starting torques (upto 4 or 5 times the nominal torque of the drive
* A wide band of constant power above base speed (again a ratio of 4 is not uncommon)
* Ability to operate effectively over a wide range of supply voltages, voltages vary much more widely in traction applications than in industrial environments.

* High efficiency over broad ranges of both speed and torque. This is particularly important for battery traction, as the battery represents a limited energy source and the range of the vehicle is then proportional to the efficiency of the drive.

The SR Drive fulfils all the above requirements, more than any other Drive system.

Figures 6 & 7 show a comparison of SR Drive with other drives in terms of the above demands.

Electric Vehicles Powered by SR Drives

Figure 8 shows the measured torque/speed characteristics in the motoring quadrant for a 2KW, 24V drive for a pellet truck, with a payload of 2 tonnes. This drive is built by Radio Energie of France. The Motor is 125mm square and 180mm long and the rated torque is 9Nm at 1220 rev/min. The controller dimensions are 280 x 170 x 100mm. The truck has a fully loaded speed of 5.2Km/Hour on the level and 1.9Km/hr. upto 10° gradient. This is significantly better than the competing, modern dc motor (which has a volume 64% greater). The peak efficiency of 82% is excellent for this small drive.

Figure 9 shows the power/speed charateristics of the drive built for a 7.5 tonne, city going, delivery vehicle using a 180V battery and designed to equal the performance of the existing diesel-engined vehicle (photo) The characteristic shows constant torque to the base speed of 750 rev/min followed by constant power to 2250 rv/min thereafter.

Finally figure 10 shows both power and efficiency curves for the British Jeffrey Diamond (Dresser) coal shearer drive. This is another severely testing application, both mechanically and environmentally, and with 100% reliability demanded. Shearers weigh between 10 and 50 tonnes, yet call for most precise control of the whole drive/transmission system. It may be of interest to note that the DC link voltage in this case was 1000V, emphasising the SR Drive's adaptability to high as well as very low voltage levels.

Operational experience with these drives have been excellent - the prototype drive (fitted to an underground conveyor) has been completely fault-free from installation some 2 years ago and has now clocked up almost 6000 hours on load.

Conclusion

The results of the above sections indicate that there is no parameter or performance characteristic which makes the SR Drive unattractive. On the contrary, in almost all respects the SR system has a significant advantage over other types of drives.

In summary, therefore it emerges that the SR Drive for a given duty will when compared to an Induction Motor Drive, have significant advantages in efficiency, frame size, starting torque, overall power/speed charateristic braking ability, maximum speed and speed range, shape adaptability, inherent stability, controbility, robustness and reliability in both motor and electronics and not least importantly the cost.

Electric and Hybrid Vehicle Developments

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US

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Electric and Hybrid Vehicle Developments

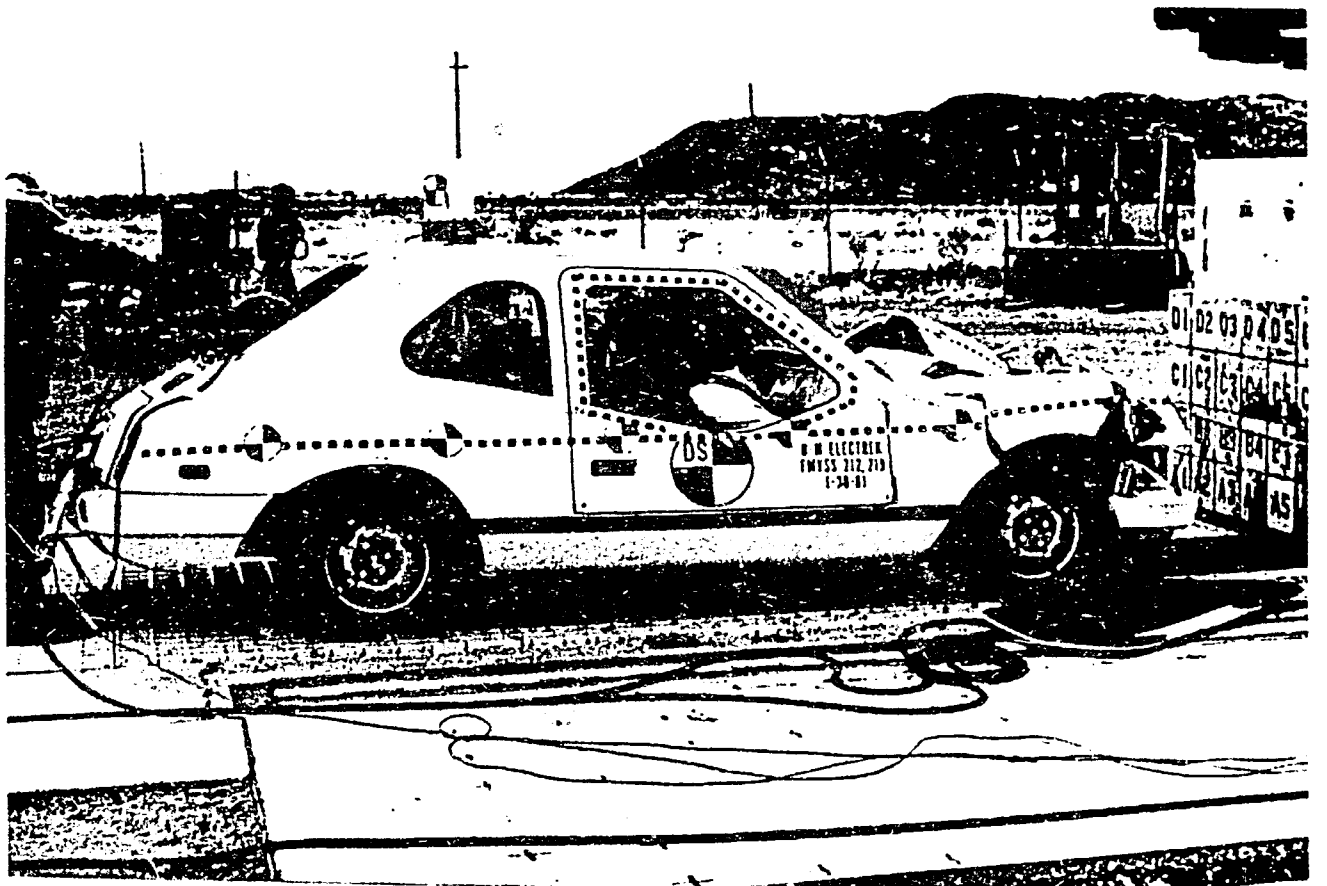
425 Corporate Circle
Golden, Colorado 80401

1995

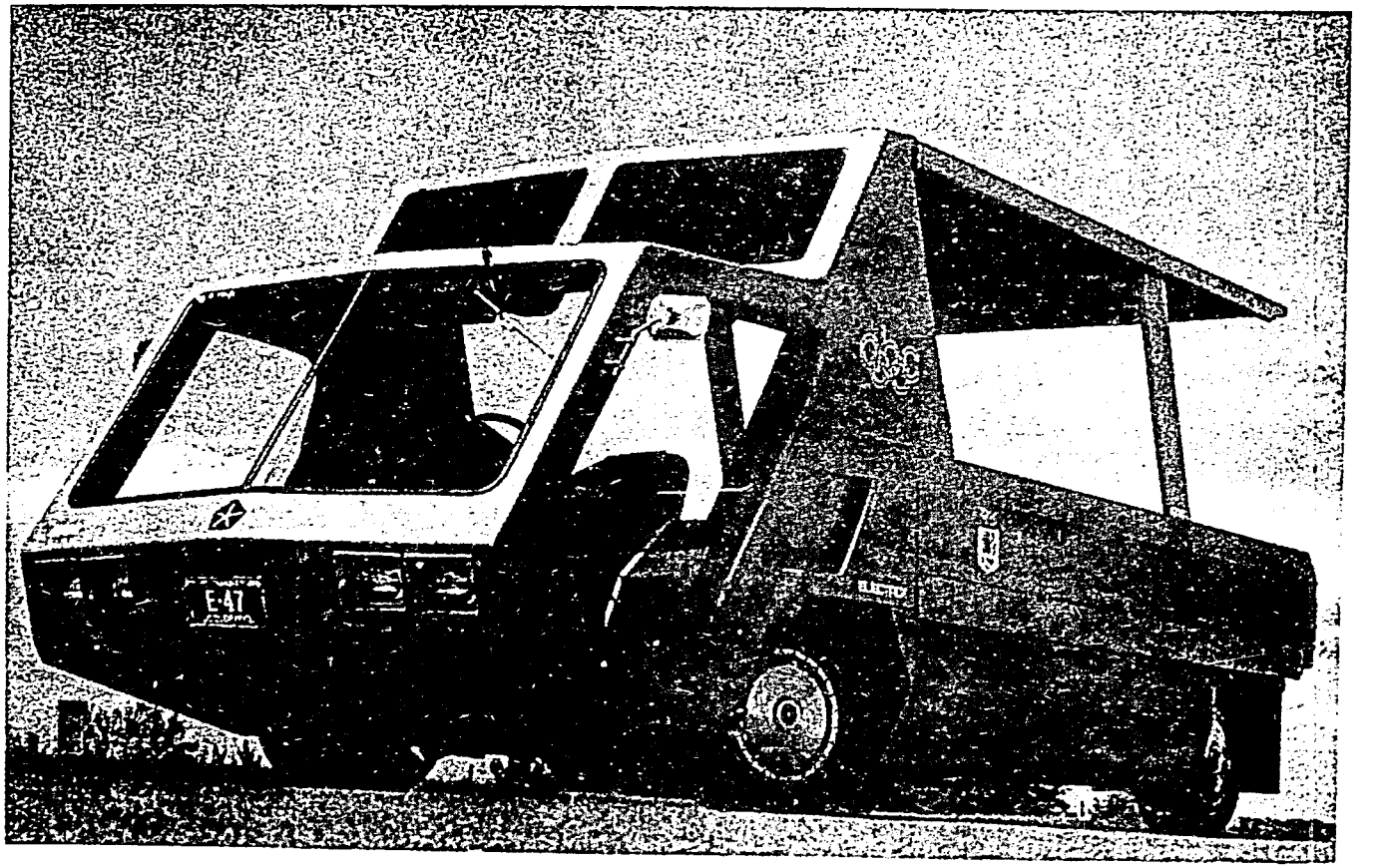
Phone: 303-278-2002
Fax: 303-278-7007

UQM

ELECTREK CRASH TEST



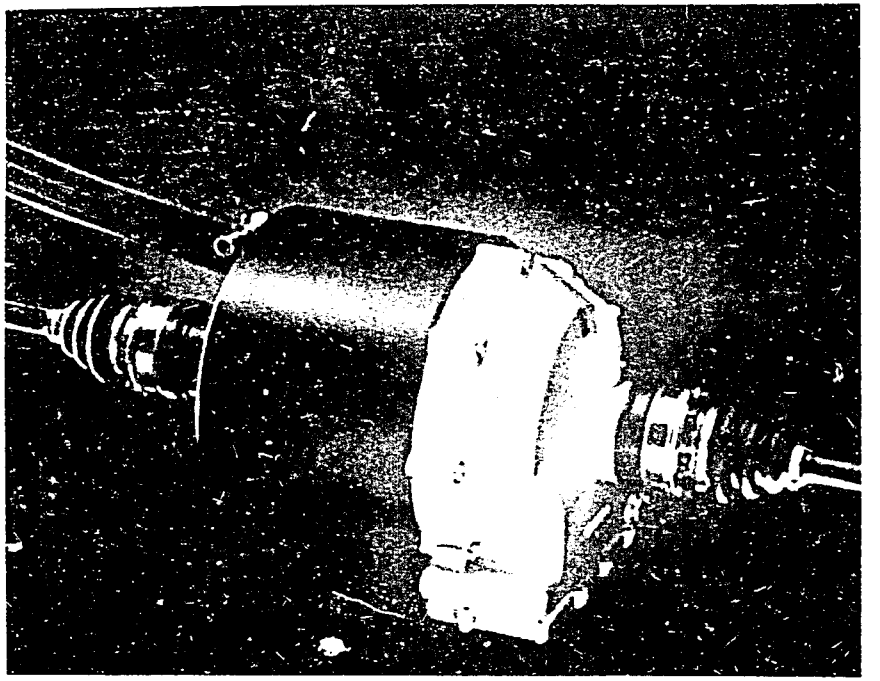
ABC TELEVISION VEHICLE FOR 1984 OLYMPIC MARATHON



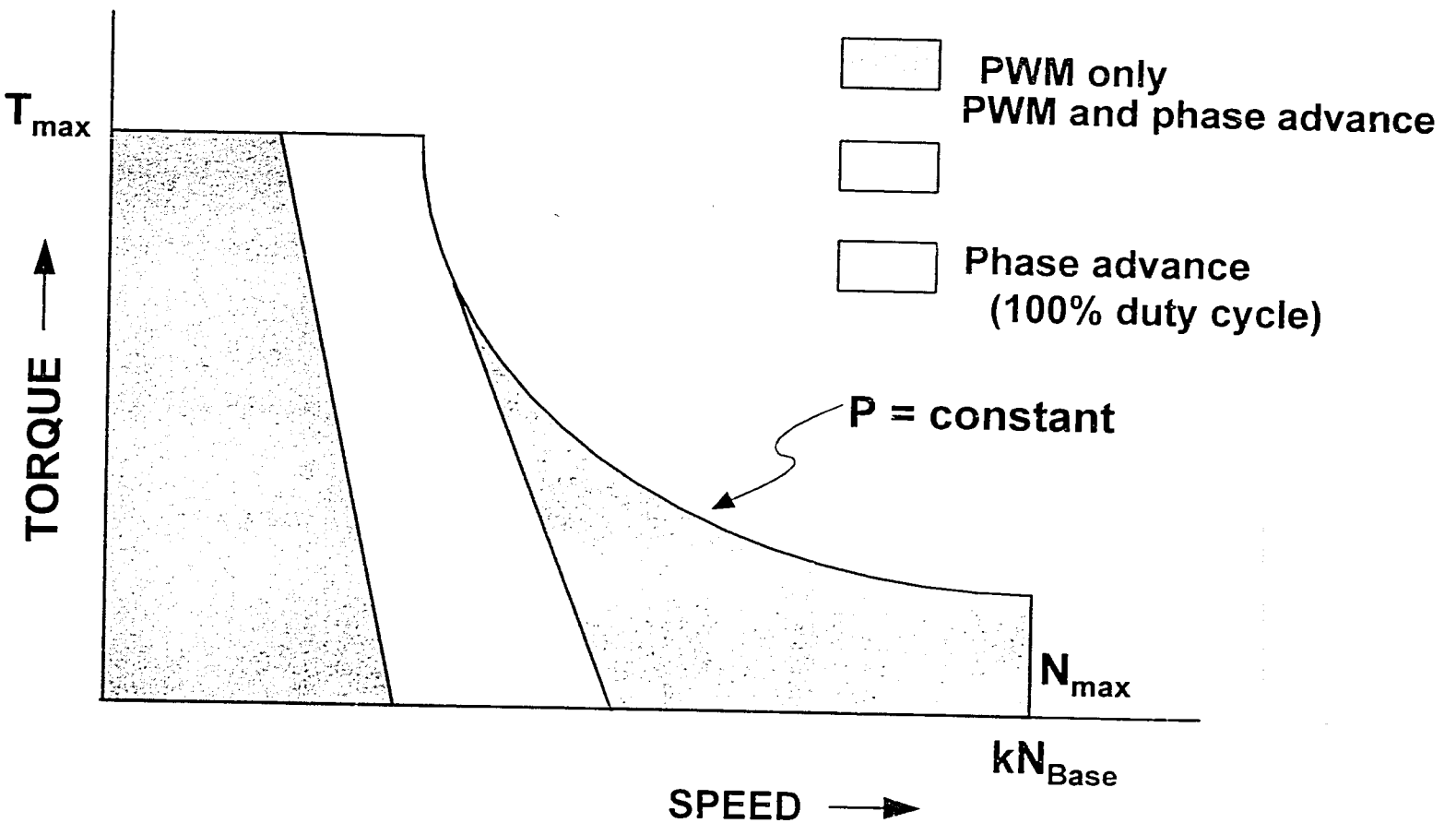
UNIQUE MOTOR TECHNOLOGY

- High power density
- High efficiency
- Permanent magnet rotors; NdFeB
- Four quadrant controllers
- Vector-controlled field modification

SR218

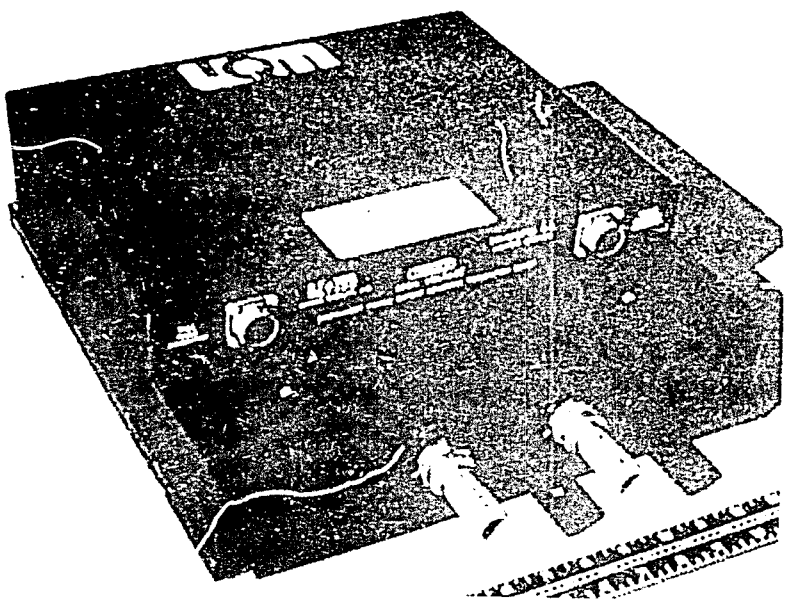


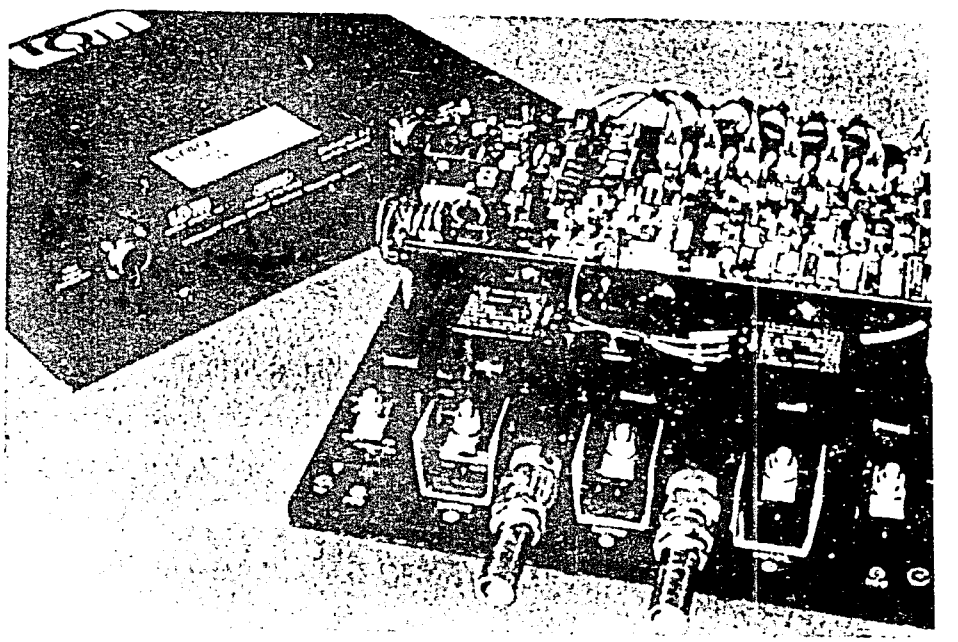
OPERATION OF PHASE ADVANCED SYSTEM



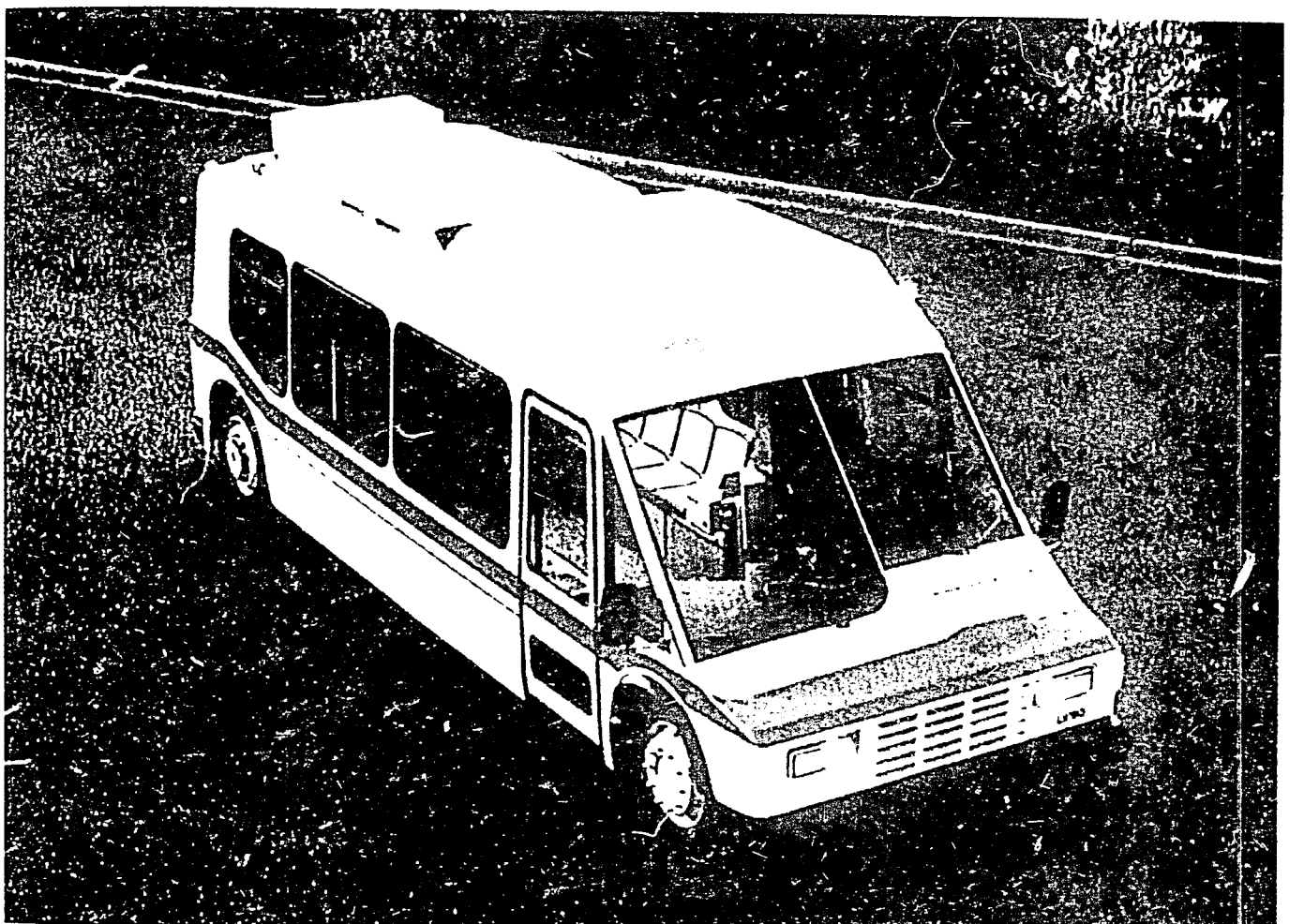
CR40-150 CONTROLLER

400 VOLT





UQM HYBRID ELECTRIC BUS



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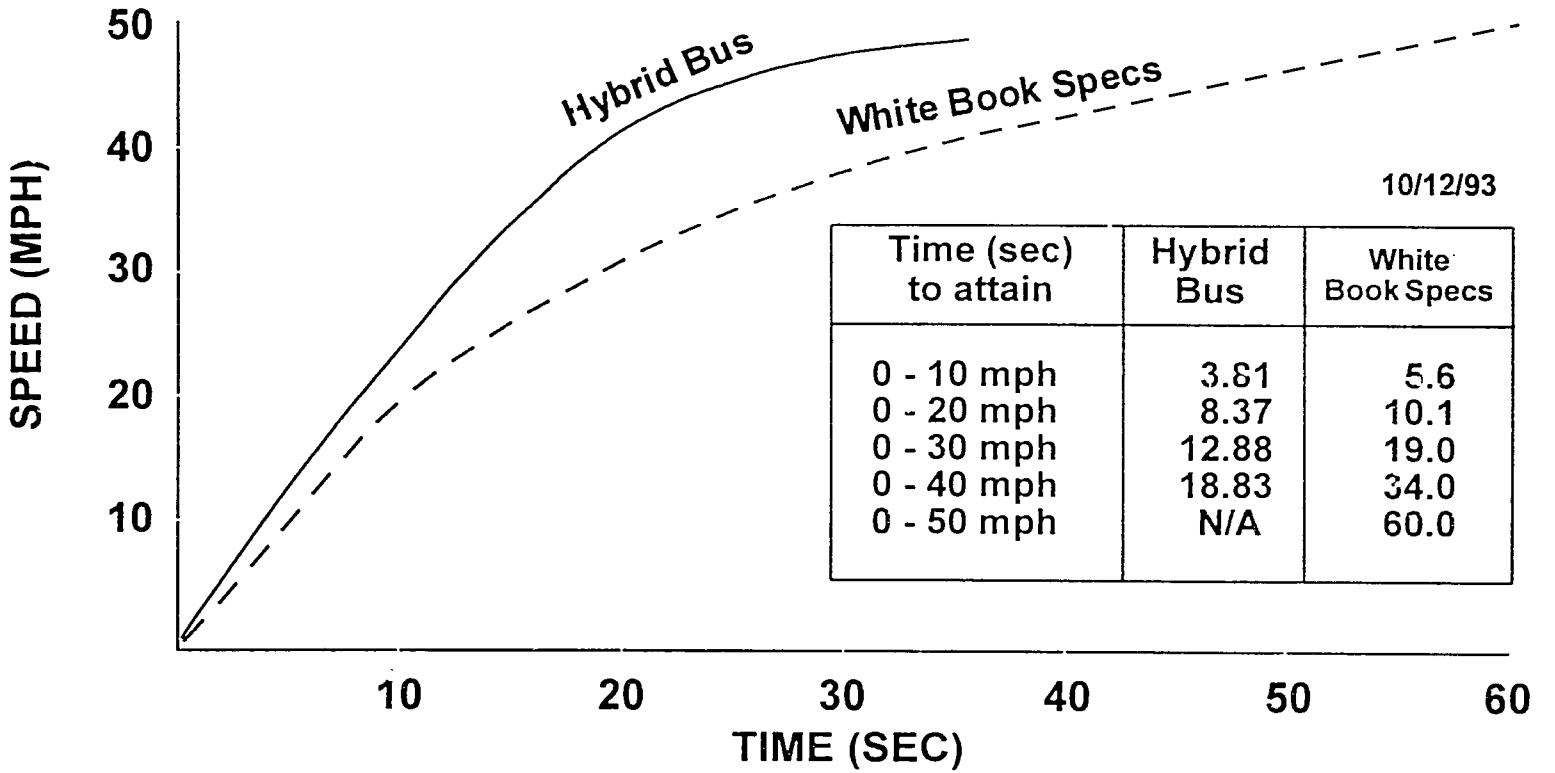
UQM HYBRID ELECTRIC BUS ACCELERATION



10/12/93

Time (sec) to attain	Hybrid Bus	White Book Specs
0 - 10 mph	3.81	5.6
0 - 20 mph	8.37	10.1
0 - 30 mph	12.88	19.0
0 - 40 mph	18.83	34.0
0 - 50 mph	N/A	60.0

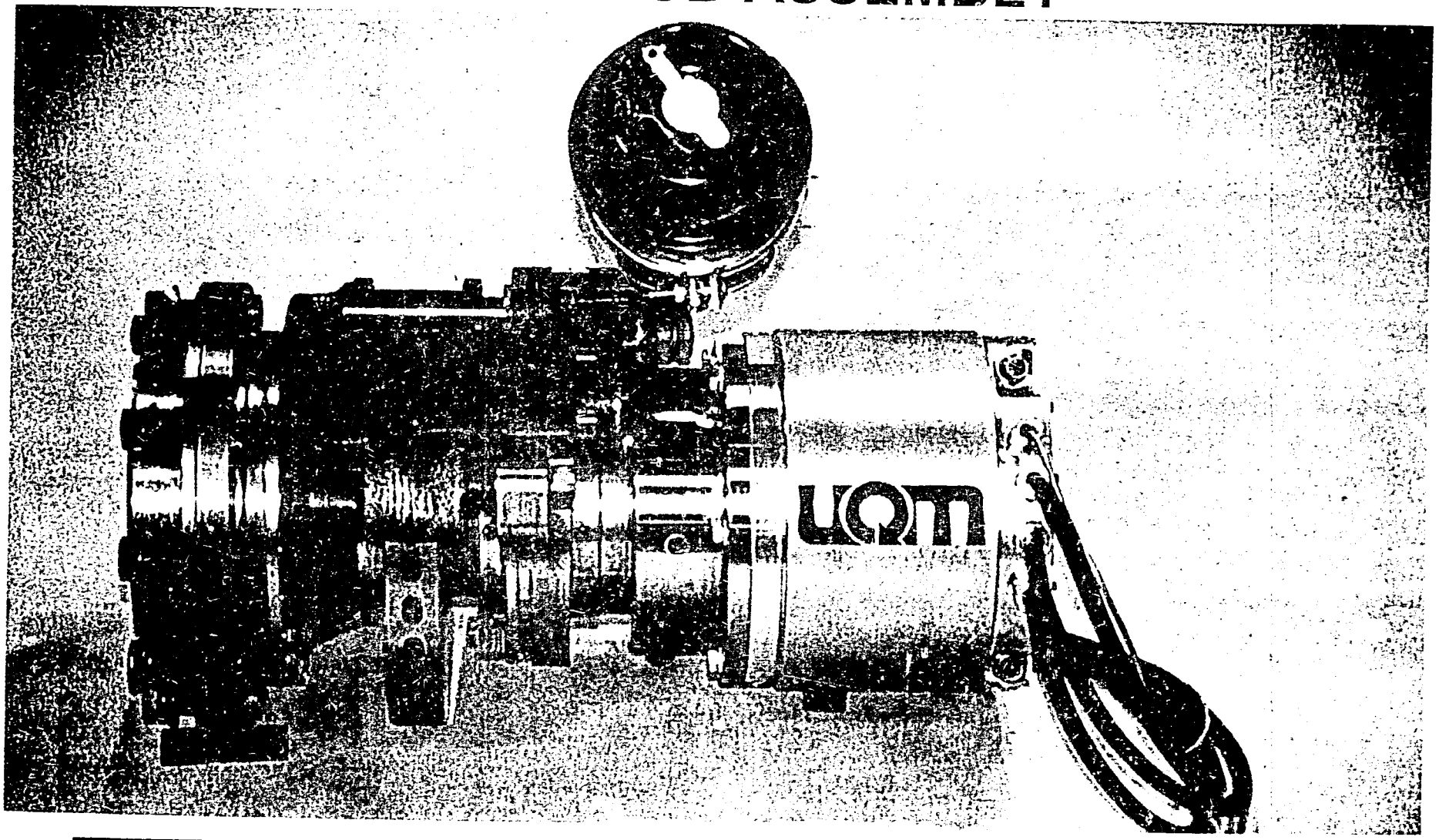
Vehicle Test Weight: 21,750 lb

Top Speed: 47.03 mph

Test Site: Bandimere Speedway
(NHRA-sanctioned 1/4 mi track)

UQM

UNIQUE 63 kW TRACTION MOTOR AND WHEEL HUB ASSEMBLY



UQM

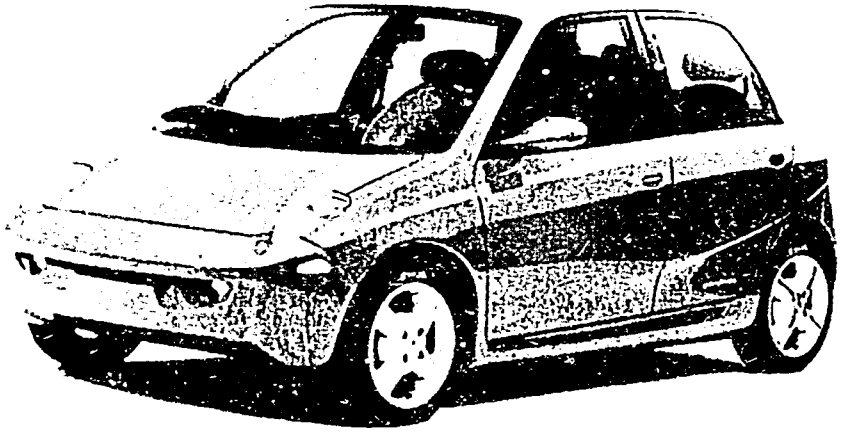
NEOPLAN 35′ COMPOSITE TRANSIT BUS

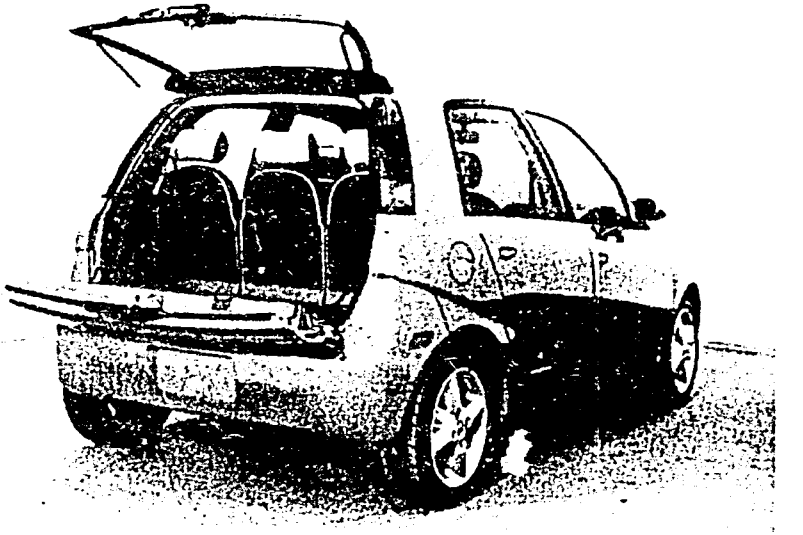
ELECTRIC FUEL = BETTER ENVIRONMENT

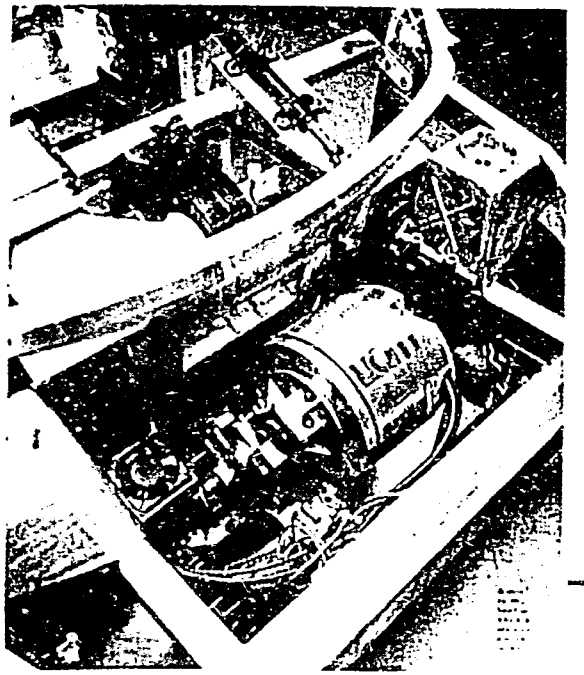
- Air pollutants from central generating plants easier to control
- Per-mile emissions lower
- No fuel to burn in accidents
- Other environmental benefits including less noise and less water pollution from highway runoff

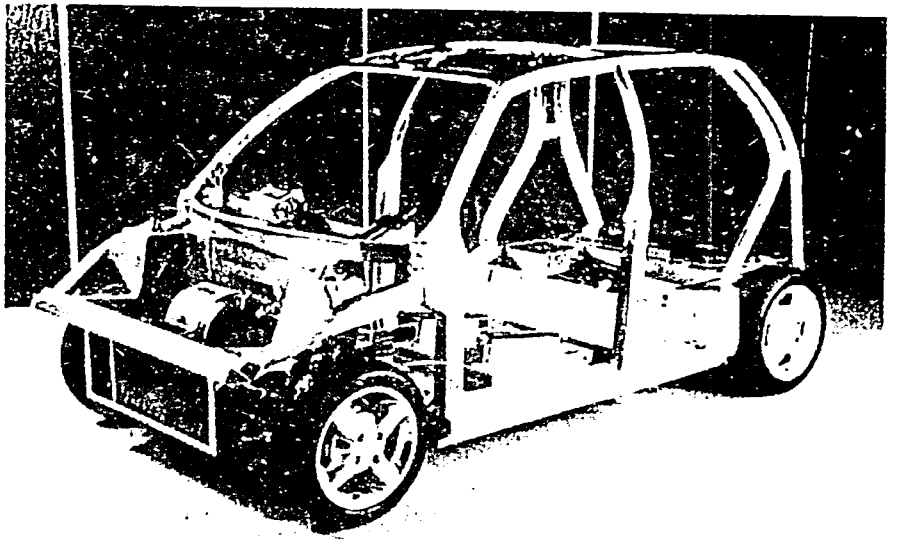
FORD RANGER-E CONVERSION

ETHOS 3 EV





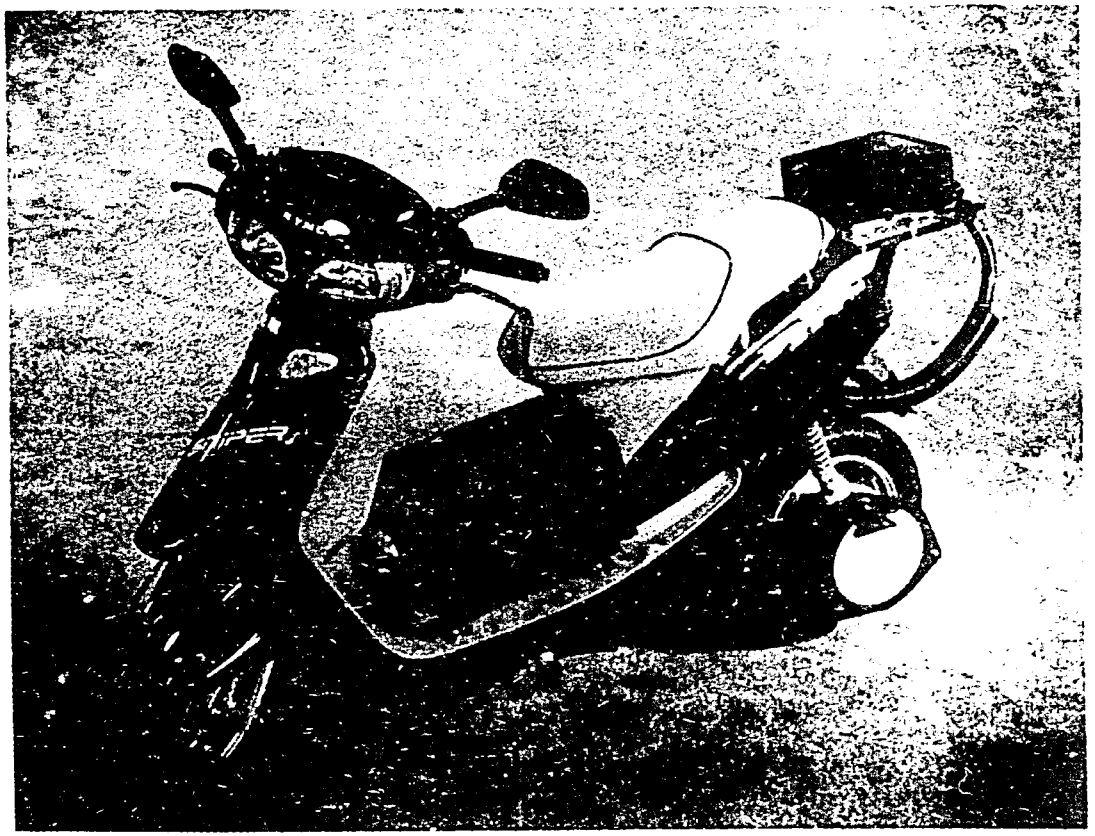




UQM

Choking the streets of Kaohsiung at rush hour, motorcycles are a commuter's best friend; islandwide, some ten million—one for every two people—vastly outnumber cars and trucks.

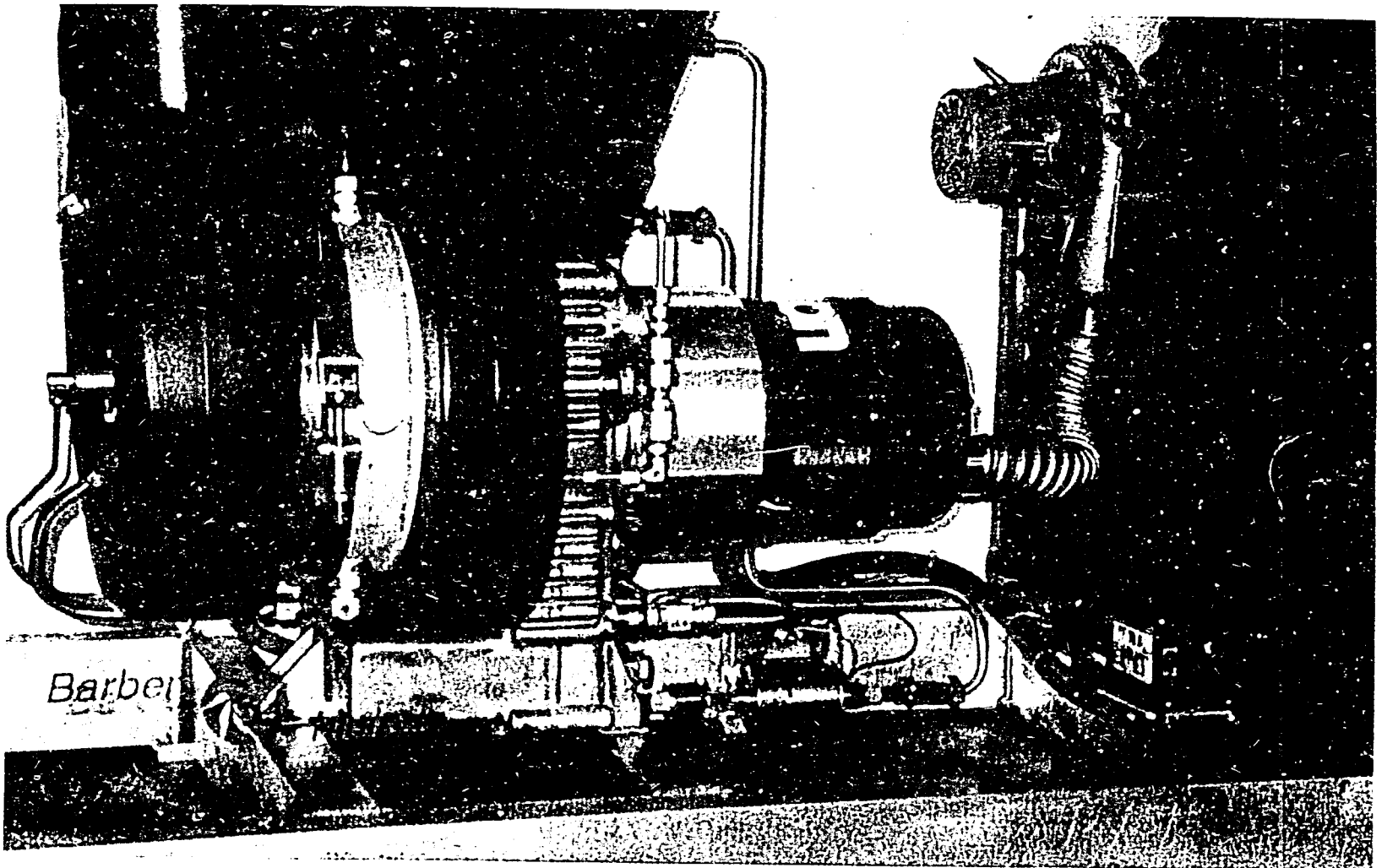
ELECTRIC MOTOR SCOOTER



FORD - DOE PROGRAM GOALS

- Increase fuel efficiency by 100%
- Meet EPA Tier II emission levels
- Achieve competitive performance, range, safety and cost
- Utilize alternate fuels
- Timing: five years and $122 million of cost-share funding

UQM/Barber-Nichols TURBO-ALTERNATOR



Electric Transportation: An Antidote to Oil Addiction

Oil Use: EV vs. CV

(Barrels per 100,000 miles)

EV

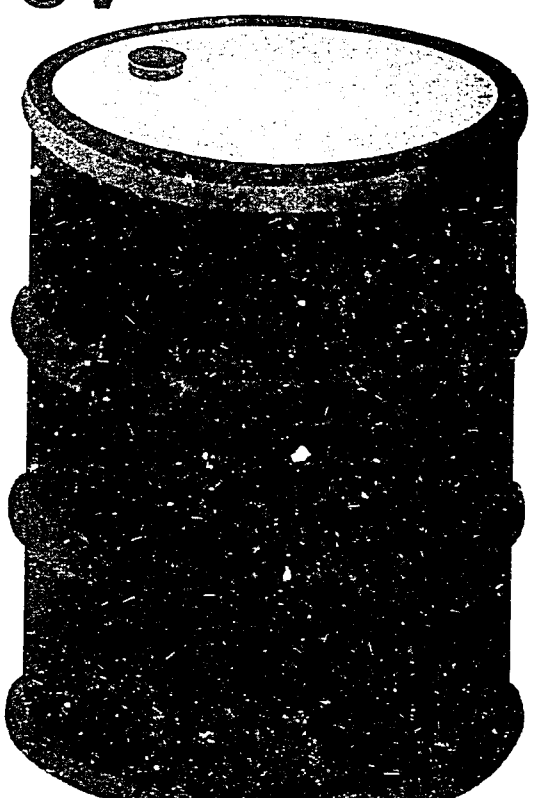
2 barrels

(@ 4 m/kWh)

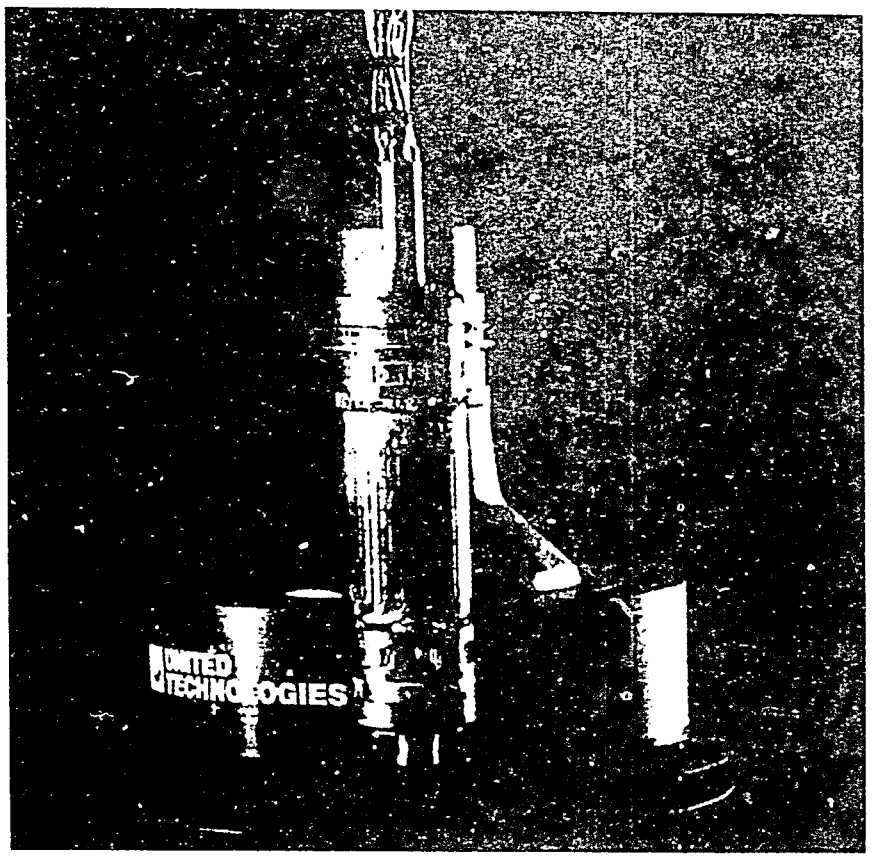
CV

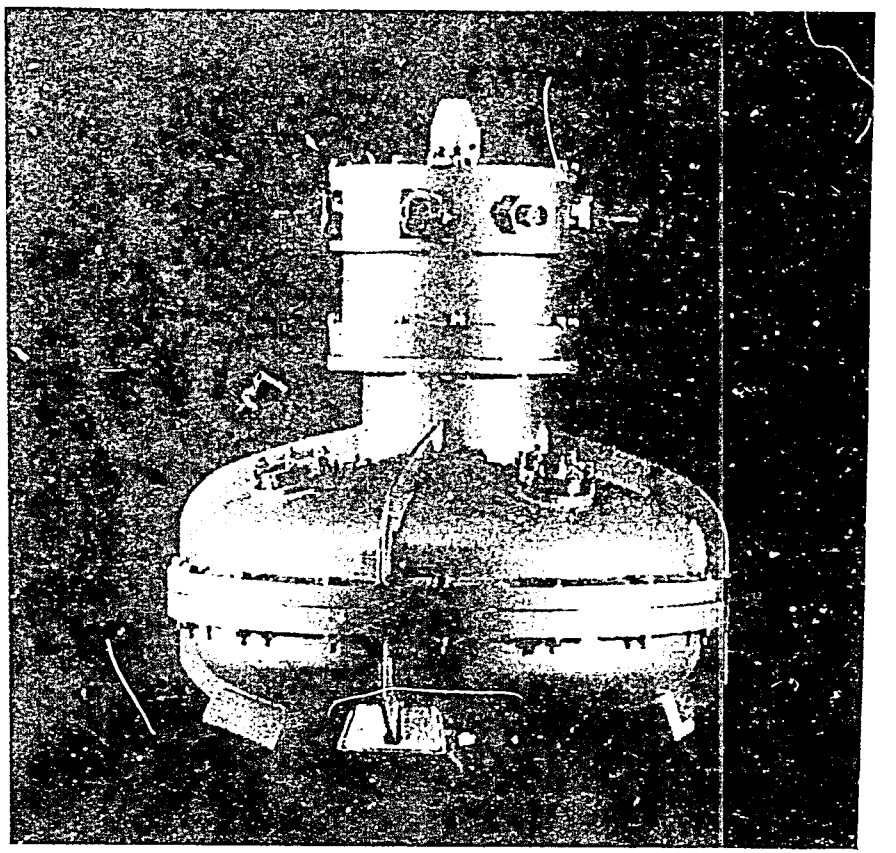
94 barrels

(@ 28 mpg)



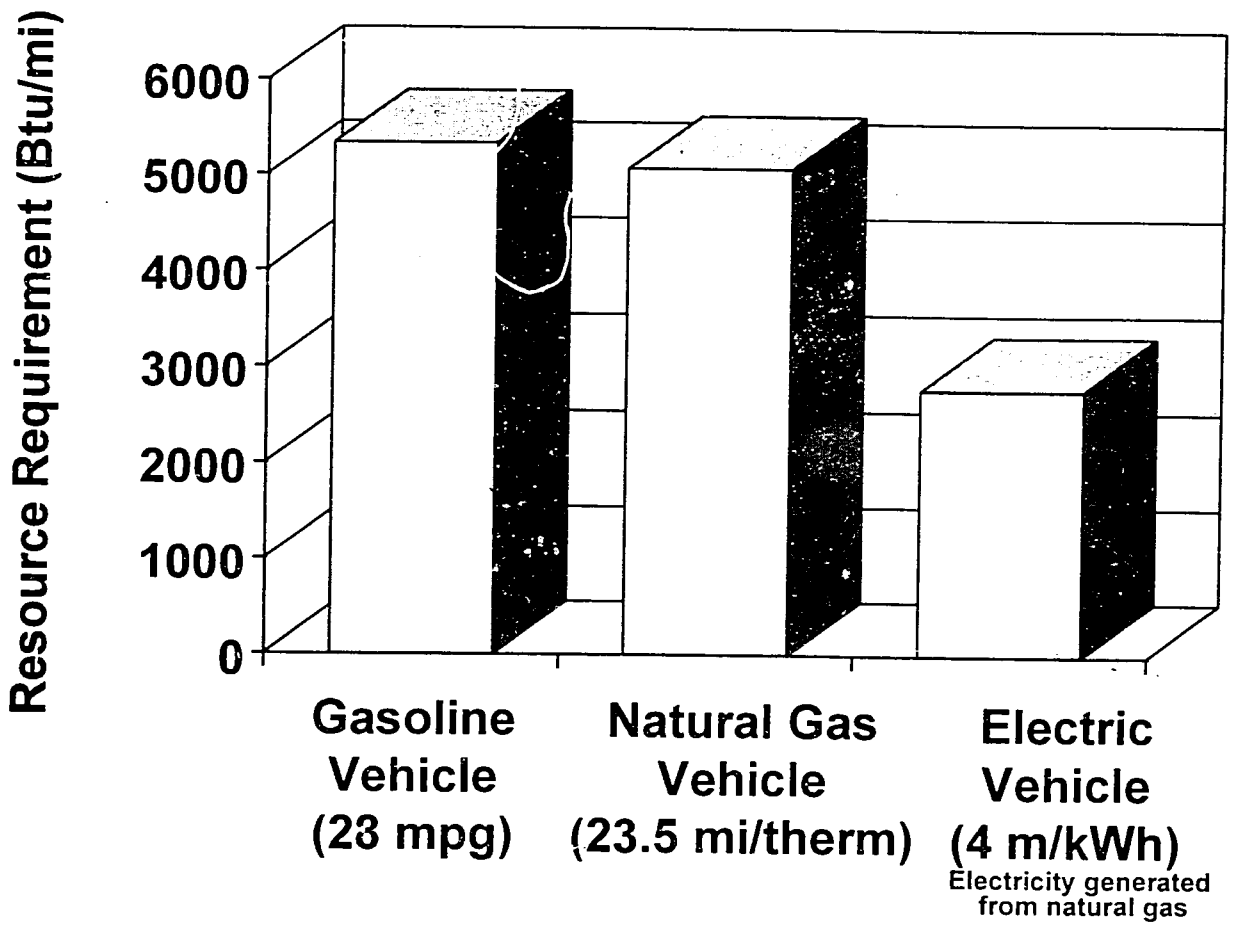
Flywheel Surge Power Unit





The Efficiency Advantage

Energy Use Comparisons for Passenger Vehicles



AREAS OF EXPERTISE

- Vehicle Design
- Electromagnetics
- Power Electronics
- Intelligent Control
- Systems Integration
- Prototyping
- Test and Evaluation
- Limited Production

Electric Road Vehicles - An Overview

Mr. P. D. Gupta
Sr. Deputy General Manager
and
Mr. H.K. Gupta
Sr. Deputy Manager
Bharat Heavy Electricals Limited,
Bhopal

1. Background : The first prototype battery operated electric road vehicle was developeed by BHEL in 1973 in association with VRDE & RDSO. Later, the task of developing commercial models of EVs was entrusted by DST to BHEL in 1979. Accordingly 10 Nos 18 seater EVs were produced during 1981-83 with funds provided by DNES. So far BHEL has produced nearly 200 vehicles out of which around 125 Nos have been supplied to DEDA. In 1993 BHEL had also developed 3 Nos 40 Passenger prototypes which are undergoing trails with DEDA. Presently, BHEL have a capacity to manufacture 300 vehicles annually, which can be augmented to produce 5000 vehicles per year. The EVs developed by BHEL are designed to run at a maximum speed of around 40 kmph and cover about 70 kms. on single charge. Over the years, following major product/system improvements have been brought about.

   * Development of a more rugged and reliable thyrister chopper.
   * Quick battery withdrawal system.
   * Increase in battery energy density from 27 to 30 WH/KG
   * Development of single phase on board battery charger.

   The vehicles produced in the country employ a direct current series compound motor fed from a thyristor chopper controller. The source of onboard power being lead acid battery. However, in the developed countries vehicles using IGBT based chopper controllers, high energy density batteries have been developed. These improvements result in simpler equipment configuration and longer range per charge due to reduction of battery weight.

2. **Development of Battery**

   The lead acid batteries available in the country have low energy density of around 30 WH/KG. This necessitates use of very heavy battery on the vehicles restricting the maximum speed and range per charge. With the developmental efforts of BHEL India Chloride and Standard Batteries, it has become possible to produce batteries of 30 WH/KG energy density. Reliance Energy Storage and System, Calcutta have developed a lead acid battery of 38 WH/KG energy density which is under field trial. Horizon Battery Technology Development USA have also developed a high energy density, fast charging, maintenance free lead acid battery of 55 WH/KG density. This battery is proposed to be produced in the country by their subsidiary Horizon Battery Technologies, Bombay. The developments will go a long way in establishing viability of EVs.

3. **Updation/Absorption of EV Technologies**

   For their various advantages, EVs are expected to find wide spread applications and acceptance once batteries of suitable energy density (and therefore low weight) are commercially available. It is, therefore, suggested that a core group of following organisations could be created to coordinate the activities to adopt/absorb the new developments/technologies in their related field:

i. BHEL : Complete electricals including motor choppers controller and vehicles assembly.

ii. CECRI Karaikudi - Battery

iii. Additionally manufacturers of diesel/petrol vehicles could also be associated for development/ supply of tailor made chassis to BHEL.

iv. Support from the Government :- Since the EVs are 2 - 2.5 times costlier than the diesel petrol vehicles, both in first cost & battery replacement cost. Government should affect suitable support/ incentive to be given to manufacturers as well as users to promote large scale use of EVs. Some of these can be briefly listed as below:-

* Exemption from Exise Duties, Sales taxes, Passenger tax, Road Tax for EVs and their inputs.
* Exemption of Exise Duty for replacement battery set.
* Import duty Exemption for all imported components/sub assemblies.
* Extend subsidies directly to perspective users including individual buyers.
* IREDA should further liberalise the financing arrangements etc.

v. * Technological trends in related field.
* IGBT chopper.
* 3 phase AC drive with inverter control.
* Impulse charging of battery in 15-20 mts.
* Charging of battery at work place or parking at market place.
* Reluctance motor drive with switching control.
* Mctor built in wheel (2 or 4 ac motors).

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

Summary of Proceedings of Technical Session

Mr. Carl Hocevar presented the paper on 'Overview of Role of Electronic/Electric Vehicles in Transportation'. During the presentation, he stated that US has been a key player in initiating EV programme: Under this programme, a number of R&D projects have been initiated for EVs. The prominent among them are projects initiated by three major auto manufacturers and US Advance Battery Consortium.

He highlighted benefits derived from operating EVs which included pollution reduction, oil saving and other economic advantages. EVs are more energy efficient and can boost regional economies in a country like India. He also referred to the legislations/regulations brought out by the US Government which have acted as catalyst in promoting EVs and creating substantial market for EVs. He emphasised the role of government in forming National Consortium for short term, medium term and long term development of advanced batteries along with the auto manufacturers, industry and R&D institutions. As a result of these efforts, advanced EVs such as Solectria and high energy density (45 WG/KG) batteries have been developed which are now commercially available. Apart from this, a network of charging facilities has also been created facilitating charging of batteries at convenient places such as petrol pump, market places, office etc.

He concluded his presentation by saying that Government has to play significant role for market development, infrastructure creation and technology development for promoting applications of EVs in India. Government intervention is also important as reduction in pollution due to automotives is a social need.

Dr. S.K. Mittal presented a paper 'Battery Development for Electric Vehicles' highlighting current international trends in battery development for EVs. In his presentation, he touched upon the problem of environmental pollution and suggested use of EVs in 2/3 wheelers and in buses for special purpose applications in India. He also referred to recent controversy regarding implementation of California legislation and efforts of big auto manufacturers in pressurising the US Government to change the legislation mandating sales of certain percentage of EVs by them in California.

He stated that technologically the critical path in commercialisation of EVs is battery and we must have break-through in battery development to have consumer acceptable EVs. He further emphasised that both price and range of EVs are serious limitations and need to be addressed urgently if we want to popularise EVs on large scale in India. In his presentation he gave comparison of different types of battery technologies commercially available, their features, and suitabilities for different types of EVs. He also described salient features of various types of EVs manufactured in Japan, Europe and USA.

While presenting the Indian scenario vis-a-vis pollution due to automotives he stressed that EV programme need to be sharply focussed and potential applications of EVs need to be found. In this context, he felt that 2/3 wheeler categories of vehicles which contribute to the pollution significantly could be replaced by EVs gainfully.

He stated that Chloride India can develop Lead-Acid Battery for meeting near term requirements in India. As a practical approach to promotion of EVs in India. Dr. Mittal suggested setting up of a consortium of all concerned Government agencies, industry and R&D institutions for development and commercialisation

of EVs. Dr. Gangadharan in his paper 'Batteries for Powering Electric Vehicle' presented trends in development of different types of high energy density green batteries for EVs such as Swing or Rocking Chair or Lithium Ion Cell and Lithium Polymer Batteries. He stated that these Cells show high voltage and high power besides being environmentally safe unlike conventional secondary cells like Lead Acid, Nickel Alkaline Cell series. The advantages of these high density cells are small size, reduced space and volume, high energy and power density. These cells are explosion free and environmentally safe. These cells will be cheaper to manufacture as raw material required is available in India. He informed that such batteries are commercially available from Yardney, USA. Many countries in West Europe, Japan, USA etc. are planning to use these batteries for EV applications.

Dr. Gangadharan concluded by stating that CECRI has requisite expertise in this field and would like to take up development of VRCA Lead Acid, Metal Hydride and Nickel Cadium Batteries for specific EV applications.

Mr. Subhash Dhar presented in his paper 'Ovonic Nickel-Metal Hydride Batteries - The Enabling Technology for Electric Two and Three Wheelers in India' an overview of his company and activities associated with development of high energy density Ovonic Battery. He also highlighted the problems associated with commercialisation of EVs and stated that the problem of limited range of EVs could now be overcome by using Ovonic Battery which is Nickel Metal Hydride Battery. He stated that Nickel Metal Hydride Battery is much more superior in performance to conventional Lead Acid Battery. This has been proved as a result of trial runs conducted by EPRI in USA using Ovonic Battery. As compared to 40-60 km range achievable from Lead Acid Battery, Ovonic battery could give 90-120 km range per charge. In addition, Ovonic Batteries could be 100 percent charged in one hour duration. He also informed about the use of these batteries by Ford, Chrysler, Honda, GM and other EV manufacturers in Singapore,Malaysia, Hongkong and his plans to set up manufacturing facility in India.

Mr. Dhar concluded by stating that Government and industry participation is a must in development and promotion of EVs in India. For this a centralised plan needs to be worked out with mandate from the Government involving existing auto manufacturers. A legislation similar to California legislation should also be introduced in India.

Shri V.N. Walivadekar presented in his paper 'Electric Vehicles and Its Drive Technology in Indian Context' status of development of electronic AC Motor drive technology for EVs undertaken by CEERI in India. In his presentation he also covered international trends in drive technology for EVs and comparison of advantages and disadvantages of different types of drives such as DC Motor, AC Motor, Switched Reluctance Motor and Brushless DC Motor Drives. He also described various technical criteria for selection of a particular type of drive for different categories of EVs.

He concluded by saying that AC Motor drive is more suited for EV application because of its advantages over conventional DC drive which is being used by most of the EV manufacturers in India and abroad. He also stated that Switched Reluctance Motor Drive is the drive of future and it is right time to initiate development of this drive in India. He suggested that it is important that appropriate drive technology is identified for a particular type of EV to get maximum advantage.

Mr. M.D. Jos in his paper 'Electronic/Electric Drive Development' presented his company's profile and gave background of initiating design and development activities for India' s first electric car Lovebird. He also informed about the in-house development work carried by Eddy Current Controls in developing DC Motor drive and chopper controller for this car. Describing his company's future plan of undertaking development of Switched Reluctance Motor Drive he stated that technology for EVs are available in India but what is required is the motivation and joint efforts by all concerned Government agencies, institutions and industry to make EV programme a success. He suggested forming a Consortium of these agencies which will help in speeding up the development and promotion of EVs in India. He also felt that in Indian situation Hybrid EVs may also prove to be a better alternative for reducing pollution caused due to automotives in big cities since potential for low volume production of such vehicles is possible.

Mr. Charles Haba through his paper presented a brief overview of the activities undertaken for development and promotion of EVs in USA and gave details of various projects initiated and completed by Advanced Electric Car Technology (AECT). While describing the efforts and role played by AECT in development, testing and integration of critical EV components such as Motor (DC/AC/BLDC), Controller (SCR/PWM/MOSFET/IGBT), Battery (Flood Pb Acid/Recombinant PbAcid/Ni Cd/Ni Metal Hydride, Zn Air/ Li Iron/Li Polymer), transmission system, battery chargers etc. He also presented a case study of the pilot project on EVs completed by AECT in USA.

Mr. Haba also informed about the various sponsored projects completed by AECT for development of different types of EVs for different agencies in USA, Thailand and also for Bajaj Auto in India. He concluded by saying that real breakthrough in EVs will come from India.

Mr. John Everton through his paper 'Electric and Hybrid Vehicles Developments' presented, in brief, his company's (M/s Unique Mobility) profile and gave details of various EV/Hybrid Ev/converted EV development projects undertaken by Unique Mobility in USA. He also informed about the Unique Motor Technology, Battery, IGBT Controller development work undertaken by them. While describing the work completed by his company on composite Hybrid Bus and converted vehicles/Ev's, he felt that their expertise in vehicle design, system integration, power electronics, testing and evaluation of EVs could be gainfully utilised in India.

Mr. H.K. Gupta of BHEL presented his companies activities and background of undertaking design and development work for different types of EVs in India for the first time. He also informed about the experience and expertise acquired by BHEL through pilot project on battery operated vehicles undertaken through government funding He also gave the details of the different types of EVs developed and supplied by them and improvements incorporated in the technology as a result of field trials and user feed back. He also informed about their plan for BHEL-CECRI joint venture programme on development of high energy density batteries and future programme on AC drive and IGBT controller. He concluded by saying that government has to continue to play an important role in development and promotion of EVs in India.

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

Fiscal Instruments to promote EVS in India

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Ministry of Non-Conventional Energy Sources
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A Battery Operated Vehicle (BOV) is a vehicle driven by electric motor energised through electric speed controller by secondary battery charged by electricity. The BOV demonstration programme was introduced by the Ministry of Non-conventional Energy Sources in 1986 with the sole objective of providing a suitable alternate to petrol/diesel operated vehicles which would help to conserve the oil, reduce outgo of foreign exchange and provide noiseless pollution free mode of surface transportation. A number of State Nodal Agencies, Public Sector Undertaking, Electricity Boards, National Park, etc. are operating these vehicles in the country.

Running and Operation Cost

As a result of the demonstration programme, a number of experiences have been gained along the learning curve. Besides the limitations of range, and speed, one of the main obstacles to the large scale introduction of battery vehicles in the country is its high capital cost due to which running and operation cost per kilometer is higher than that of equivalent capacity diesel vehicle. This is depicted in the Table 1. The cost per kilometer for a 18 seater BOV is Rs.23.23 without any incentives and for a 18 seater diesel vehicle is Rs.7.79. The same comes down to Rs.10.93, if the BOV is fitted with two sets of battery packs and Government subsidy of Rs.2 lakhs and soft loan from IREDA at low interest rate for purchasing battery vehicle are taken into account.

Table - 1

Comparison of Running and Operation cost of Battery Operated Vehicle (BOV) and Diesel Operated Vehicle (DOV)

			BOV	DOV
1.	CAPACITY	:	18 SEATER	18-SEATER
2.	COST (WITH 2 SETS OF BATTERY)	:	RS.9.2 LAKHS	RS.2.75 LAKHS
3.	LIFE	:	10 YEARS	7 YEARS. 1,50000 KM
4.	COST OF 1ST SET OF BATTERY	:	1.2 LAKHS	—
5.	2ND SET OF BATTERY	:	1.5 LAKHS	—
6.	LIFE OF BATTERY	:	1000 CYCLE	—
7.	KM/CHARGE (1 SET OF BATTERY)	:	60 KM	—
8.	(2 SETS OF BATTERY)	:	120 KM	—
9.	SALVAGE VEHICLE	:	5%	10%
10.	SALVAGE BATTERY	:	15%	
11.	WORKING DAYS	:	300/YR	300/YR
12.	ELECTRICITY	:	43 kwhr/charge Rs. 2.5/kwhr	7 km/lit of diesel Rs. 7/lit of diesel

	BOV (1 Set of battery, No Subsidy) with Bank rate of interest of 22%	BOV (2 Sets of battery Rs. 2 lakhs subsidy) & Bank rate of 22%	BOV (2 Sets of Battery Rs. 2 lakhs subsidy) IREDA rate of interest 10.5%	DOV No Subsidy Bank rate interest (22%)
1. Vehicle Depreciation	4.22	1.60	1.60	1.65
2. Interest on vehicle	9.77	3.66	1.75	2.88
3. Battery Depreciation	1.7	1.41	1.41	—
4. Interest on battery	1.46	1.65	0.78	—
5. Electricity	1.45	1.45	1.45	(Fuel) 1.00
6. Maintenance	1.75	2.50	2.50	1.35
7. Salaries	2.88	1.44	1.44	2.8
TOTAL	23.23	13.71	10.93	9.76

Financial and Fiscal Incentives

For neutralising the higher running and operating cost of BOV for its promotion, the following financial and fiscal incentives are given by the Government:-

1. 100% depreciation in the first year.
2. IREDA loan for 75% of the capital cost at the interest rate of 10.5% repayable by 5 years.
3. Subsidy of Rs.2 lakhs for a 18-seater battery vehicles with 2 sets of battery packs.
4. Subsidy of Rs.50,000/- on select models of Industrial model battery vehicles.
5. MODVAT facility for manufacturer.
6. Battery set fitted in Battery Operated Road Vehicles (BORV) as OEM, tyres, tubes and flaps of BORV are exempted from excise duty.

Proposals under consideration

To provide incentives for neutralising the higher running cost of a BOV, some proposals are under consideration as depicted in Table 2.

Table - 2

Proposals of Fiscal Incentives under consideration

Items	Excise Duty At Present	Excise Duty Proposed
1. Full Electric Vehicle	10%	2%
2. Battery Pack for Second set of battery and replacement set of batteries	25%	NIL
3. Chopper for Battery Vehicle	ED-15% SC-15%	NIL

Conclusion

Fiscal and financial incentives cannot alone solve the problem of higher running cost of battery vehicles. Further research and development works should be taken up for development of high energy density battery for higher range, quick charging, higher payload, suitable chassis and efficient electronic trains like controller, motor etc. so that limitations of EVs are minimised, paving the way for technoeconomic viability.

Introduction of Electric Vehicles in Indian Cities - The Challenges and the Strategies

Mr. A.N. Shukla
Consultant
Peerless

Introduction

The increasing concern around the world over the pollution caused by road vehicles has lead to an intensive search to control this pollution.

The strategies are basically two pronged:

i) Improvement of the efficiency and cleanliness of the fossil fuelled engine and

ii) Development of alternative prime movers.

The most important development in the second field is the electric vehicles or EV.

This is also the only vehicle which qualifies as a Zero Emission Vehicle.

While considerable technological progress has been made in the development of electric drive systems and controllers the major issues which have so far stood in the way of wider adoption of the electric vehicles are:

Chart I & II

Issues

1 THE COST

2 THE RANGE

3 THE INFRASTRUCTURE

Let us look at these three issues.

Cost

The cost of the electric vehicles is higher in comparison with the cost of a fossil fuelled vehicle of equal size and performance because:

a) While the fossil fuelled vehicle is mass produced and gains from the economies of scales, the EV is still in the hand crafted or batch production stage. Even medium volume production is a year to year and a half away both in Europe and America. Motors and the controllers are yet to be mass produced.

b) The cost of the battery represents a substantial additional capital investment when compared to the cost of the fuelled vehicles .

Battery leasing can be one method to handle this problem.

ii) **Range**

The range of the electric vehicle is determined by the energy storage capacity of the battery.

Some very high energy density batteries are now becoming available for use on electric vehicles such as Sodium-Sulphur, Nickel Metal Hydride , Lithium Polymer,etc. Some of these per Kg than the Lead Acid and Nickel- Cadmium batteries. Their life expectancy and cost per KW/Hrs in commercial production is however still being worked upon . Meanwhile we have the work horses i.e. Lead Acid and Nickel cadmium batteries. These have a rather limited energy storage capacity.

A 350-450 KG Lead Acid Battery, replacing a 35 Ltrs fuel tank would give a range between 70 and 120 Kms against 400-600 for tank of petrol.

Until batteries of higher energy density become commercially available, the electric vehicle should not be expected to compete with the fossil fuelled vehicle for inter-city traffic. It has however already become a practically, clean and environment friendly alternative for city traffic.

III. Infrastructure

The basic infrastructure requirement of the electric vehicle is a charging station. As compared to 15 minutes needed at a petrol/diesel pump for the conventional automobile, the normal charging time of the battery is six hours and more.

A charging station therefore must have space to park the vehicle for the time taken to charge the battery, which, would normally take place when vehicle is otherwise idle i.e. at night or while it is stabled at or near the place of work.

Public parking lots, institutional parking lots and other open spaces in the cities could be potential charging stations.

Home charging is clearly a choice for those who have the facility to charge at home at night.

Rapid charging at special rapid charging stations is another alternative.

Whatever method or combination of methods is adopted, setting up of infrastructure requires a coordinated effort by government authorities city administrations, the power utilities as well as the electric vehicle and battery manufacturers.

It needs to be understood that while the electric vehicle has already become a viable and practical means of cleaning the air and protecting the environment and is the only Zero Emission Vehicle, it will need governmental and institutional support to bring it through its nascent stage to reap the advantages of its eco-friendliness while overcoming its limitations vis-a-vis a fossil fuelled vehicle.

Global Strategies

Before enumerating issues on which policies need to be formulated to make the EV a success, it would be relevant to recount some of the efforts which are being made by Governmental Institutions and Utility Companies and manufacturers. These are only illustrative of what is happening around the world.

Chart - III

1. United States of America

California has taken the lead by legislating that from 1998 two percent of all vehicles sold in California must be ZEVs. This would guarantee a sale of about 50,000 vehicles per annum. By the year 2000, five percent and by 2003 ten percent sales will have to be ZEVs. Another 10 states are likely to follow. The Federal Government has enacted a Federal Clean Area Act to support this process.

2. France

France has launched a F.F. 550 million programme to introduce several thousand EVs on French roads by the end of this year. They have also decided that an EV support infrastructure must be established in atleast 10 cities by the end of this year. EDF, the National Power Utility of France are actively involved and have made a substantial investment which includes setting up of three types of charging stations in public and private parking lots, including rapid charging stations where the battery can be charged at the rate of approximately 30 seconds per Km of energy requirement.

The Ministry of Environment, Ministry of Industries, Municipal, Administrations particularly of the cities of Toulouse and La Rochelle where pilot projects have been launched are also actively involved, together with the car builders, Peugeot and Renault.

3. **Germany**

Government Policies to support EVs include:

(a) Exemption from excise duty for all electric vehicles for 5 years.

(b) Proposed enactment of legislation on the lines of the State of California to make sale of Zero Emission Vehicles compulsory.

(c) Funding of Electric vehicle R&D for the construction and testing of more than 300 proto-types by German Car Builders.

(d) Germany is also contemplating direct Public Sector support by laying down programme guide lines for Public Sector undertakings like the Post Office, Telecommunication etc., to prescribe a minimum specific percentage of purchases of electric vehicles.

4. **Switzerland**

A number of free charging stations has been provided in public car parking areas in Geneva. Several mountain resort towns have banned fossil fuelled vehicles. ZERMATT, one of the most popular mountain resorts, has 400 EVs.

5. **Italy**

Municipal Energy Company of MILAN has developed a network of charging stations for the use of EV owners.

Policy Issues

Chart - IV

The issues on which policy decisions need to be taken are therefore :-

1. Coordinated projects for setting up of infrastructure, which would involve central and state government, city administration, automobile manufacturers and battery manufacturers.

2. Legislative support to encourage the use of electric vehicles to clean the city environment, which can take the form of low levies and fees for EV ownership, such as reduced registration fee and road tax, exemption from sales tax, soft loan for purchase of EV etc.

3. Subsidized power tariff to the EV users and charging stations.

4. Exclusion of city centres and other ecologically threatened areas from access to fossil fuelled vehicles including the concept of park and ride.

5. Institutional and Governmental support to the EV in the form of preferential buying for fleet operation.

6. Governmental support and subsidy to setting up of charging stations and battery leasing programmes.

7. Incentive to the manufacturer in the form of preferential allotment of industrial sites, financial subsidy, customs, excise and sales tax concessions, soft loans etc.

The Peerless Group has entered into a Joint Venture with M/S. Frazer-Nash of U.K. to manufacture an electric vehicle. The first model, which was on display at the exhibition, is a mini Taxi to replace to autorickshaw. This will be followed by a family car for city diriving. The vehicles will be powered by a battery which will be supplemented by the power of the sun by solar cells.

CHART I

ISSUES		
COST	:	SMALL VOLUME PRODUCTION; COST OF BATTERY
RANGE	:	LIMITED BY BATTERY STORAGE CAPACITY
INFRASTRUCTURE	:	NEED CHARGING STATIONS

CHART II

SOME BATTERY OPTIONS

	LEAD ACID	NiCh	NiMH	NaS	LITHIUM POLYMER	ZINC AIR	ZINC BROMINE
ENERGY DENSITY Whr/Kg	31-35 (50*)	40-35	60-72 (120@)	80-150	150-200	185-200	75-80
LIFE CYCLE	300-600*	700-2000	1000@	600+	?	?	?
COST/KWHR	Rs. 2000-6000	Rs. 30,000	Rs. 6000@ (At present Rs. 3 lakhs)	Rs. 6000@ Rs. 3 lakhs	Rs. 3000@ Rs. 1.5 lakhs	Rs. 3000@	Rs. 4500@ Rs. 9000.@

NOTE : * CLAIMED FOR ADVANCED Pb ACID BATTERY
@ FUTURE PROJECTION

CHART III

U.S.A.	FRANCE	GERMANY	SWITZERLAND	ITALY
LEGISLATION THAT A FIXED PERCENTAGE OF VEHICLES SOLD ARE ZEVs. - CALIFORNIA - TO BE FOLLOWED BY OTHER STATES	PLANNED INTRODUCTION OF THOUSANDS OF EVs ON FRENCH ROADS BY YEAR END - EV SUPPORT STRUCTURE IN 10 CITIES BY YEAR END - PILOT PROJECTS FOR INFRASTRUCTURE IN CITIES OF TOULOSE LA ROCHELLE	- EXEMPTION FROM EXCISE DUTY FOR EVs - LEGISLATION ON CALIFORNIA PATTERN; EV R&D FUNDING BY CAR BUILDERS; DIRECT SUPPORT THROUGH PUBLIC SECTOR PURCHASE	- PROVISION OF FREE CHARGING STATIONS IN GENEVA. - BANNING OF FOSSIL FUELLED VEHICLES IN RESOPT TOWNS	- DEVELOPMENT OF A NETWORK OF CHARGING STATIONS FOR EV USERS

CHART IV

POLICY DECISIONS NEEDED

1. COORDINATED SCHEMES FOR INFRASTRUCTURE INVOLVING CENTRE, STATES AND CITY ADMINISTRATIONS AND AUTO AND BATTERY MANUFACTURERS.
2. LEGISLATIVE SUPPORT TO ENCOURAGE USE OF EVs BY:
   - i) IOW IEVIES AND FEE FOR EV OWNERSHIP
   - ii) SUBSIDISED POWER TARIFF TO EV OWNERS & CHARGING STATIONS
   - iii) EXCLUSION OF FOSSIL FUELLED VEHICLES FROM CITY CENTRES AND OTHER ECOLOGICALLY THREATENED AREAS
3. GOVT. INSTITUTIONAL SUPPORT IN PREFERENTIAL PURCHASES
4. GOVT. SUPPORT TO CHARGING STAIONS AND BATTERY LEASING PROGRAMMES
5. SPECIAL INCENTIVES TO MANUFACTURERS OF EVs

Rationale and Applications of Electric Vehicles in India

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Vice-Chairman and Executive Director
Chatelec Vehicles (I) Ltd.
Bombay

Rationale

1. **Pollution**

Delhi, Bombay, Calcutta are 4th, 5th, 8th most polluted cities in the world.

Bombay is under the Metropolitan Environment Improvement Programme of UNDP

Air Pollution ranges are 27,000 metric tonnes per annum out of which 60% is from vehicles.

Each Internal Combustion car emits 4 times its weight in carbon dioxide.

Over 130 km, it emits 2 kg of carbon dioxide, 500 gms of hydrocarbons and nitrogen dioxide.

Resultant major pollutants:

Sulphur dioxide, ozone	-	Irritation of lungs & eyes
Carbon monoxide	-	Headaches impaired judgements, fatigue
Nitrogen dioxide Particulates Hydrocarbons	-	Acid rain, destruction of acquatic life

We are concerned about our monuments and the negative effects on liberalisation and tourism.

The example of U.S.A. declaring 2% zero omission vehicles by 1998 and 10% by 2003.

USAID could give us the exact laws and the World Bank report on pollution in Asia.

The Press has done commendable work in the last 10 years, to highlight pollution.

There is a Supreme Court Committee on Vehicular Pollution. Losses due to Health, Productivity, Natural Resources, loss in tourism and foreign investment should be quantified so as to get the true cost of electric vehicles, after deducting these costs.

At 90 decibels, we are probably the noisiest country in the World. EV noise is 7 decidels less than conventional vehicles.

2. **Oil**

As a result of the decreasing sources of oil, change over to EVs is more urgent.

India has 15 years stock of oil.

India Imports 30 million tonnes p.a. of crude oil.

Increased demand more than the estimated 6%.

Gas in India at 24 years' stocks is already a priority need for fertilizer, power stations.

Coal meets about 213 years requirement of coking coal.
219 years non-coking coal.

World oil stocks are for about 25 to 30 years.

Our foreign exchange is more borrowed than earned. J.P. Morgan predicts a current account deficit of $ 5 million next year.

Electric vehicles are 88% energy efficient as against 35% in the case of ICs.

3. **Easy to Maintain**

EVs have 1/3rd no. of parts as compared to Internal Compustion Cars.

They have Longer lives

There would be no danger of spare part pilferage

There would be no petrol pilferage.

Alternatives to EVs

These alternatives are not feasible in India. Reasons for thse are:-

(i) CNG is in short supply and is hazardous.

(ii) Methane - corroding

(iii) LPG is in short supply.

Myths regarding EVs

Myths which require to be exploded.

" EVs are only road vehicles"

" There have to be advances in technology"

" Operating costs are higher"

" Threat to ICs"

" First costs of EVs should be lower than ICs even though technology has to be compromised on".

Suggested Uses

Chatelec's 9 pure electric vehicles models exist in India.

Most of them are 100% indigenous.

60% of the users are the Government departments like Utilities, Industry, Defence.

10% of these uses in 11 sectors, can be by EVs.

The savings would be to the tune of Rs. 2400 crores for 10,000 vehicles at 91-92 sales nos.

Due to the increased uses in the government department, economies of scale will result and the Private Sector users may also then follow .

An effort from the government's side is also needed to make a policy decision of having at least 10% EVs in these sectors.

Methodology of Introduction

1. Clean Air Islands should be introduced in Metropolis.
2. Nothing but EVs in one out of each of the following Industries for campus use.

1. Petro Chemicals
2. Steel
3. Electric supply.
4. Fertiliser
5. Atomic Energy

3. 25 road vehicles and 25 industrial vehicles to be taken by each Ministry for the 11 public sectors under their control.

Fleet uses will force learning of maintenance and training.

Then the stage will be ready for individual users.

Other Policy Decision Required

Cheaper finance @ 6% rate of interest should be made available for the purchase of EVs.

Extension of the same level of subsidies to industrial models as well as for road models, as they save in pollution and oil and have no range constraints.

Waiver of road taxes as in other countries.

Waiver of tendering procedures and deposits for SSIs.

Off peak night rates for charging, usually should be 1/3 cost.

More Necessary

Government sponsored promotion campaigns.

Free use of T.V.

Funded exhibitions and demonstrations

Training courses.

Finally

A networking of organisations like PCRA, Energy Management Centre, Pollution Boards who are spending funds unrelatedly, towards the same aim.

These funds have to be focussed to specific demonstration and implementation programmes and suggest specific alternatives.

The oil companies to take upon themselves to set up charging stations at petrol pumps in collaboration with EV manufacturers.

New Technology

First priority should be to those technologies which lead to

1. Lesser maintenance
2. Quick charging

Second priority to those technologies which :

1. Increase range and
2. Speed

Suggested Uses of Electric Vehicles

Industry	:	Material Handling & Personnel.
Railways	:	Haulage of Parcels, at Workshops etc.
Airport/Defence	:	Movement of: Baggage/Containers & pallets/Step Ladder/Aircraft/Ground Power Unit/ Water Bowser/Toilet Water & Refuse/ Passengers/Workshop equipment and spares/mobile step ladder/ Maintenance van/Catering Van/Bulk Freight Loader/Crew Carrier/Monitoring with Walkie Talkie/Cleaning Crew Van.
Municipality	:	Committee Vans Ambulance Health/Medicine Van Disinfectant Van Meat or Fish Van Scrap Van Silt Van Refuse Tipper Delivery Van Garbage Van
Tourism	:	1/2 day tours around precious monuments.
Post & Telegraphs	:	All POs within 20 kms. Special delivery to large customers.
Road Transport	:	Ring Routes/Elite areas/crowded areas/ Workshops.
Dairy	:	Neaby Milk Booths/Mobile Sales Van/ Anciliary Milk Products.
Govt. Inter Ofice Use	:	Staff cars - 5 seater. Van for movement of Staff - 11 seater - 20 seater
Police	:	Staff Car Monitoring Walkie/Talkie Vans Breakdown Vans Towing Vehicles.

Perspective on Electrical Vehicles

View Point of an Automobile Manufacturer

Mr. Tapan Basu
Bajaj Auto Ltd.
Pune

I. Electric Vehicles - The Background

A. Introduction

Electric vehicles have been in existence from the end of the last century - as a matter of fact well before the advent of the massive numbers of fossil fuelled vehicles that we see around us today. The reason for the proliferation of Petrol and Diesel fuelled vehicles is easy to find - they offer the best form of affordable mobility, in comparative quiet ad comfort. However, this advantage has not been a winner all the way.

1. Environment

The extraordinary rise of vehicle population has brought forth a major shortcoming of this form of transportation - massive environmental degradation leading to serious health issues and considerable loss to a nation's economy. The issue has become urgent enough to merit immediate action worldwide. The most visibly active concern seems to be in the State California Air Regulation Board (CARB). This has become a model for the rest of the world, certainly to dissect and debate, but, more importantly, to instill a sense of extreme urgency. This has thrown up a technical challenge to find ways of protecting our environment without degrading our life style.

The major thrust of the regulation has been to plan a drastic reduction of polluting emissions from present day vehicles by a phased introduction of various proportions of Transitional Low Emission Vehicles (TLEV), Low Emission Vehicles (LEV), Ultra Low Emission (ULEV) each reducing the emission level to half the previous value, and finally leading to Zero Emission Vehicles (ZEV). In the projected scenario this is expected to bring down emissions of Fleet Average Non Metallic Organic Gases (NMOG) to 25% of its present value by year 2003.

2. Depleting Reserves of Fossil Fuels

Of as much importance as the emission issue is the realisation, that, almost our entire mobility is dependent on a single source of energy i.e. fossil fuels, in the form of Petroleum Oil and Gas. There is a real threat that, at its present rate of consumption, this source is likely to be severely depleted in our own lifetime. This limited resource needs to be preserved for those priority applications for which alternate sources of energy may not be convenient. Hence, General Transportation, which is, by far, the largest user, will have to find alternates in the near future.

There is, therefore, an urgent need to find a source of energy, which, not only must be long lasting, but, in the present context of environmental issues, non-polluting.

3. The India Scene

In India, there has been growing concern at the extremely high levels of atmospheric pollution in the major cities. There has been a rapid growth of pollution (2x = 4x in the last 20 years) in the urban centres of the country. Alongwith this, has come, a similar explosion in the number of vehicles on the roads. The vehicle population grew at over 16% p.a. in the last 10 years, with negligible growth in available road area. this has resulted in a significant reduction in the average vehicle speed, which, when coupled with an increased vehicle population, has congested the downtown areas and have lead to unbearable levels of atmospheric pollution.

4. Alternate Fuels

To seriously curb urban pollution, one of the suggested method is to promote, for automotive use, the use of those alternate fuels which produce considerably lesser amount of pollution. However, before any practical alternate can be proposed, it most be capable of convenient usage in a vehicle.

The primary attribute of any energy source for automobiles, is, its ability to satisfy the needs of the driver in terms of distance and drivability (acceleration and speed). A measure of this ability can be expressed in the form of two parameters:-

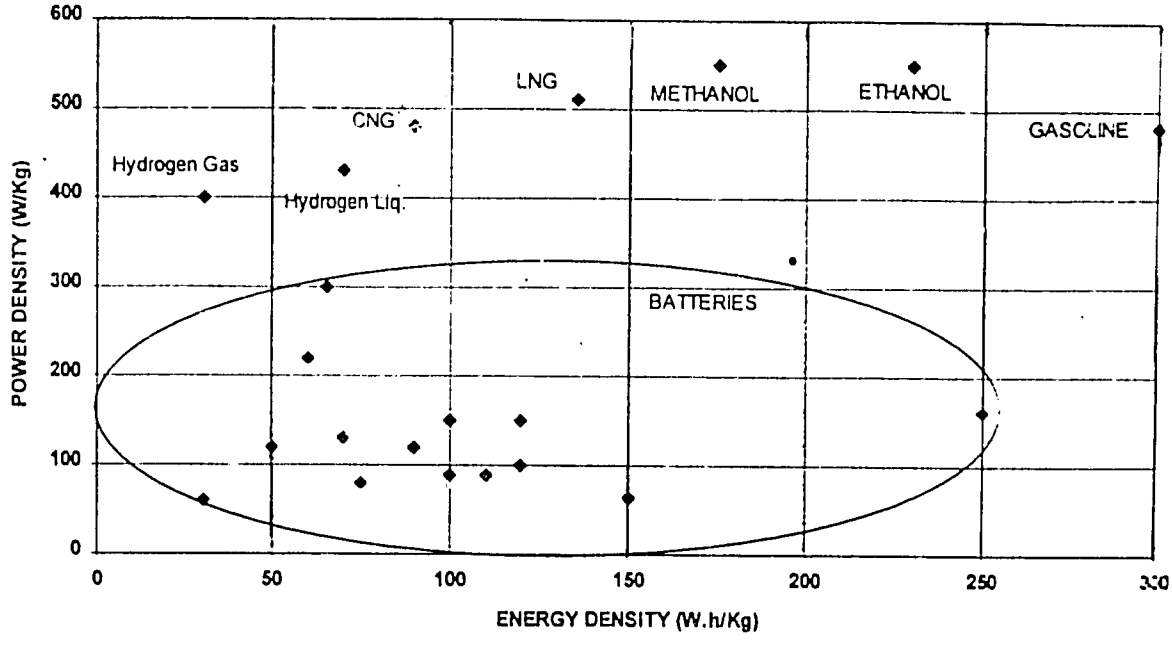
* Specific Energy Density - a measure of how far one can travel
* Specific Power Density - a measure of how fast one can accelerate, or, go

In a conventional automobile, this energy is provided by petroleum derivates like Petrol and Diesel. These fuels have high values of these prime attributes.

Fig. 1 gives a quick picture of the relative merits of some of the competing alternate fuels to petrol (gasoline).

Comparison of Alternate Fuels

Fig - I



Petrol also has high

* Volumetric Energy Density and
* Volumetric Power Density

Meaning that relatively large amounts of energy and power can be packed into a small volume. With such excellent performance indicators, it is very difficult to topple them from this lead position on pure technical considerations.

All the alternates shown in Fig-I fall short of the capabilities of petrol. This means that use of alternative fuels will, in various degrees, compromise the performance of automobiles in which they are used. However, because of their ability to produce cleaner energy, their use in the range of ULEV - ZEV vehicles is being seriously considered.

Of all the alternates shown, a true ZEV can be realised only by Battery Powered Electric Vehicles (EV). Batteries, however, are far behind petrol in their performance indicators. Hence, if EVs are to a viable alternative, it cannot challenge the gasoline driven vehicle head on, but try and meet the requirements of a specific operation, such as short distance intracity commuting, at the end of which, batteries will need to be replenished by charging.

There are, however, alternatives proposed to overcome the shortcoming of EVs in terms of their drivable range. These proposals envisage the use of a secondary power source, in the vehicle, to boost its range. Methods suggested include.

* Secondary, petrol/ alternate fuel engine-generators sets in a Parallel or Series combination - this is not a true ZEV combination but canbe classified as an ULEV proposal
* Flywheel operated generator sets in a Parallel or Series combination
* Solar cell chargers
* Fuel cell chargers

The above combinations are major technologies on their own, and merit a deep study. Due to the limited nature of this presentation they are not being considered here. This presentation will attempt to focus on ZEVs only i.e. EVs.

B. Types of Electric Vehicles

Electric vehicles are used, even today, in sizable numbers for specialised applications. Briefly, they can be categorised as:-

1. Industrial - e.g. Forklifts, Pallet trucks, Intra factory Goods movement etc.
2. Recreational - e.g. Golf-carts
   a) Bus/Light Trucks
   b) Cars
   c) 2/3 Wheelers

The first two applications form a distinct group of their own, due to their well defined and specific nature of application. The Road Transportation segment is more difficult to define, as, this encompasses an usage pattern which can vary from, say, a dash to the corner drugstore, to, hauling tons of cargo cross-country. Each of these usage pattern has its own peculiar thrust area and its own compromises. To address all these is beyond the scope of this paper, and hence, this presentation is limited to the Personal Transport sector.

C. A Case for 2 and 3 Wheeled EVs

In India, no significant attention has been given to, nor, work has been done on the commercial exploitation of EVs. Hence, we have, necessarily, to turn to USA, W.Europe and Japan, where the issue is urgent, and where, EVs have been studied, prototypes run, and, there are ongoing debates in public forums on their immediate introduction.

In these countries, the predominant mode of transportation are cars, and where, whether conditions, safety regulations and the comfort levels demanded, add significantly to the total energy required to run them. When all these requirements are added up, Electric Cars seem be unable to meet the expected levels of performance. A case is being made out for a serious look at the field of Ultra-Lightweight EVs including motorcycles, scooters and 3 wheelers runabouts, as alternate forms of transport in the suburban - downtown usage area.

However, India has an economy that is significantly different from the countries mentioned above. Ownership and usage patterns of vehicles are also different. The types of vehicles in use in the urban areas, and, their projected population can be summarized as in Tables I & II.

Table I - Modal Split

Mode	Share of Passengers (%)	
	Average	Range
Bus	69	—
Car	8	2 ~ 22
3 Wheeler	3	0.5 ~ 23
2 Wheeler	19	2 ~ 22

Table II - Travel Demand 1991 -> 2000 A.D.

Mode	Share of Passengers (%)	Increase in # vehicles (%)
Total Travel Demand	+ 600	900
Bus	69 => 55	17/p.a.
Car/Jeep	8 => 7	4/p.a.
3 Wheeler	3 => 2	13/p.a.
2 Wheeler	19 => 35	26/p.a.

From these Tables it is evident that 2 and 3 Wheelers will, in the foreseeable future, overshadow the usage of cars as personal transport in the urban agglomerates of this country.

Hence, considering the experience of the developed nations, and, the population explosion of 2 & 3 Wheelers that are expected, in India, in the next few years, there is a strong case for the industry to consider 2 & 3 Wheelers as a most promising candidate for EV technology in this country.

D. INDUSTRY PERSPECTIVES

In view of this, the 2 & 3 Wheeler industry, now engaged in the manufacture of conventional I.C. engined vehicles, need to consider EVs as a developing part of its future business. However, prior to any serious effort being mounted by the Industry a few questions, like those below, need to be answered:-

1. Who is the target customer?

Since over 40% of all 2 Wheelers and 80% of 3 Wheelers are owned and operated in the urban areas of the country, and since, the incidence of pollution is maximum in these areas, it seems legitimate to assume

that the target customer for EVs is today's urban dweller, and, who is most likely to use his vehicles in these restricted areas. Thus the Industry can presume that the sale potential will remain the same as now, for the urban areas.

2. What are his expectations?

If the EV is to become a viable alternative to the present genre of fossil fuelled vehicles, it will have to meet the expectation of the customer, in terms of:-

a) Usability

It is redundant to say, that, for any product to succeed in the marketplace, the customer must see it meeting his requirements. Thus, not only should the EV provide him with his daily transportation needs (limited to a large extent to commuting from his home to work and back, and, with short trips for shopping), but, also allow him occasional inter-city journeys of around 100 - 200 Km., to be completed in relative comfort andsafety. A study of the usage pattern of vehicles on Urban Indian roads show the following (Tables III & IV).

Table III

Average Distance Travelled

Mode	Occupancy Per Passengers)	Distance travelled (km)
2 W	1.5	25
3 W	1.8	75
Car	2.6	26

Table IV

Reason for Travel

Reason	%
Work + Education	70
Leisure	22
Others	8

It is therefore fair to assume that a significant part of a customers needs are met if an EV can provide assured range of, say, twice the distance as in Table III.

For the occasional intercity traveller, it may be adequate to provide him the desired range by a reasonable number of stops for refueling. If such refueling stations are easily accessible, and if, it can be accomplished without much loss of time, the negative impact of these frequent stops may be minimal.

b) Affordability

Today's customer of Petroleum Fuelled vehicles is accustomed to a certain historical price structure. To promote the EV as a commercially viable proposition, it is essential to project it, at least, as affordable as at the present. This must address, not only the issue of Capital Cost, but also costs related to Consumables, Periodic and Major maintenance.

) Reliability

eliability is, of course, of utmost importance, as, without a highly reliable product, no serious customer ase can ever emerge. Again, the yardstick for this will be the present vehicles on the road.

What are society's expectations?

Ecofriendliness - not just where the EV is actually used, but encompassing its total manufacturing o - disposal envelope. Hence, attention (and convincing answers) have to be provided on issues such

as the generation of energy required for manufacture of component parts, and, generation, transmission and distribution of the enormous quantities of Electricity required as fuel for the EV's - providing for these should not itself turn out to be an environmental bugbear.

Industry will also have to address itself to the issue of disposal of waste products from these vehicles, especially, as it is known that some materials in use in batteries are highly toxic.

b) Energy efficiency - so that society is not again caught in another round of resource crunch. The issue of the source and efficiency of energy utilisation is of a global nature and must carefully consider the resources and technology available in the country today. EVs should e able to wean the transport sector away from over-dependence on the petroleum industry.

4. What are target volumes projected in the various phases EV introduction (Study/Pilot production/ Volume manufacture etc.)?

At this point of time, there is unlikely to be a definite set of figures which can be projected, as, the costs involved and infrastructural requirements are hazy. However, clear, unambiguous answers and commitments will have to be generated, well in time, if the Industry is to consider making a serious effort, and, the project is not to die a premature death.

The Industry, on its part has to determine whether the targets set before it are reasonable, and, whether it can put out, on the road, sizable quantities EVs at affordable prices, provide the infrastructure necessary to maintain and run them, and, arrange for disposal of toxic and other non-environmental-friendly by-products.

II. Industry Projections - Introduction of EVs

A fair case has been made out in favour of focussing our attention on 2 and 3 Wheelers as a prime prospect of EV conversion. Unfortunately, with all the attention focussed on cars in the US and Western European countries, not very much is generally heard of the development in the field of 2/3 Wheeled EVs.

However, it may surprise to quite a few, to learn that, serious work has been going on in the laboratories of most of the better known manufacturers of 2&3 Wheelers like Piaggio in Europe, and, Yamaha/Honda/ Suzuki in Japan. These manufacturers have vehicles, either, in Pilot production or already introduced into the market.

In addition, laboratories of known experts in the field of Electric Propulsion/EV Conversion like Westinghouse/ U.S. Electric Car/AECT in USA, Tokyo R&D/Chibu, Kyshu and Kansai Electric Power Cos. in Japan are also attempting to promote these products.

Serious attempts are being made in Taiwan, and Bangkok to introduce 2 and 3 Wheelers, in the city traffic, on priority.

Hence, there is likely to be considerable experience already available to base our own projections on. Available information can be collated to generate pointers to some of the broad areas that need to be addressed.

A. Major Components

When we shift from conventional vehicles to EVs, certain components need to be replaced. These can be classified as:-

1. Energy Source: The Battery

There are various forms of Electric Batteries, but all practical batteries depend on some form of a Chemical Reaction (reversible/irreversible) to produce electricity. Due to the requirement of easy refurbishing the source of energy, batteries used for EVs use reversible chemical reactions where the reaction that produces electricity to drive the vehicle is reversed during the process of recharging. The battery

technology is a prime area of research and quite a few combinations of materials have been developed as potential candidates for EV use. To qualify as a serious contender for EV use a battery has to be judged from various aspects, other than the four (specific Power and Energy Densities, and, Volumetric Power and Energy Densities) mentioned earlier. Some of these are:

a) Quick Charging rate - which allow a depleted charge to be quickly replenished, thus making it friendly to long range driving.

b) Large Cycling capability - to allow it to be repeatedly charged and discharged without losing its inherent capacity to store energy.

c) Extended operating environment - to allow it to be used in climatic extremes without significant deterioration of performance.

d) Low cost - a major cost being that for batteries requiring periodic replacement.

e) Low self discharge rate - which allows the battery to remain disused for long periods of time without losing any significant part of its stored energy.

f) High efficiency - so as to reduce cost of electricity from the utilities, which is utilised for recharging, to a minimum.

g) Long Shelf life - to allow it to sit on the shelf for a large number of years without any significant capacity loss.

h) Low maintenance - to reduce both down time as well as running cost.

i) Abuse resistance - to be as high as possible to prevent inadvertent damage in case of misuse.

Unfortunately no single battery type meets with all the requirements. Even in the main parameters of Specific Power and Energy Densities, there are trade offs. To these must be added the Volumeric efficiencies, available technology for mass manufacture, and, cost.

To progress focussed research into these aspects of EV technology, large companies have come together to pool their resources. The most celebrated is the consortium formed by the "Big three" US automobile manufacturers and the U.S. Department of Energy (DOE). This consortium, known as the USABC (United States Advanced Battery Consortium) have laid down specific goals in the Medium and Long terms Fig-II and Table-V show how different battery technologies compete today.

Fig – II

Comparison-Battery Types

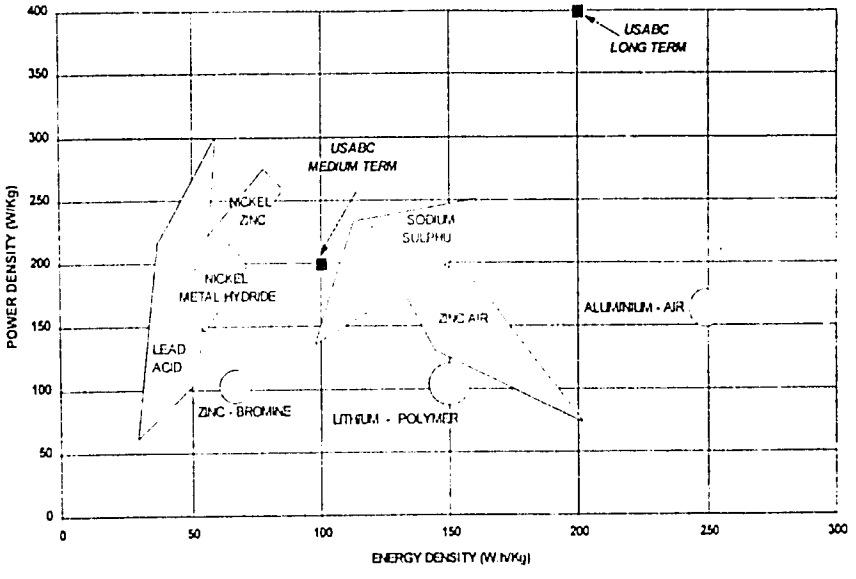


Table V
Properties of Batteries

BATTERY TYPE	SPECIFIC DENSITY		VOLUMETRIC DENSITY		CHARGE TIME	EFFICIENCY	CYCLE LIFE	SELF DISCHARGE	COST	COMMENTS
X	POWER (W/KG	ENERGY W.H/KG	POWER (W/L	ENERGY (W.H/L)	Hrs.	%	#180% DOD	% In 24 Hrs.	US $/ KWh	
Lead	70 = 300	30 = 60	✖	75	1 = 8	70	600	✖	70 = 130	Cheap; Limited Energy: Heavy; *Lead is toxic*
Zinc Bromine	100	80	✖	55	✖	75	500	✖	150 = 300	Good performance: Readily available materials: Costly; Requires pumps and *hazardous Bromine*
Nickel Zinc	170 = 260	55 = 85	✖		✖	✖	200	✖	200 = 500	Costly;
Sodium Sulphur.	140 = 280	100 = 160	✖	85 = 125	✖	90	800	✖	200 = 1200	Good performance; Costly; *Possibly dangerous materials;* High temperature
Nickel Metal Hydride	150 = 220	55 = 75	✖	150	✖	80	699	✖	200 = 800	Good Performance: Costly materials & manufacturing
Lithium Polymer	100	150	✖	130	✖	95	700	✖	50 = 500	Manufacturing likely costly; *Lingering safety fears*
Zinc Air	80 = 225	120 = 200	✖	✖	15 min	60	100	✖	100	Good performance: Refuel requires replacement of part of battery
Aluminium Air	160	250	✖	✖	15 min	✖	Mech recharge	✖	✖	Excellent performance; Refuel quick but requires replacement of part of battery
USABC-Med. term	150	100	250	135	<6	75	600	<15	<150	
USABC-Long. term	400	200	600	300	3=6	75	1000	<15/mlh	<100	

✖ - DATA NOT AVAILABLE

From the comparative performance and cost figures, it is evident that the choice for an energy source for EVs in the near future is limited. For 2 and 3 Wheeler, where the capacity to carry large weights and volume is severely restricted, the choice is even narrower. Considering the cost penalties, the choice is possibly limited to the trusty Lead Acid in its more modern incarnations, and perhaps later, when mass manufacture brings costs down essentially to material costs, to new technologies like Zinc - Air, Aluminum - Air, and, Lithium - Polymer, and Nickel - Metal Hydride.

A major parameter for choice of a battery type will be its ability to substantially recharge in a very short time. If this time can be nearly the same as that taken now to fill up petrol, the negative effect of limited range of EVs will be largely eliminated. If not, quick battery replacement at roadside stations may have to be provided.

2. Prime Mover : The Motor

The second major component whose performance is a key factor affecting vehicle performance is the Electric Motor. Major requirements for this product are:-

* Low Weight and Volume.
* High torque capabilities at low speeds for quick acceleration.
* Capable of high sustained power for comfortable driving.
* High Efficiency
* Low cost
* Low maintenance
* Long life

Though conventional motors still dominate over the newer technologies, new performance demands, matching with advances in the Power Electronics Technology, are mandating a shift towards more efficient and cheaper products. Newer designs use advances in magnetics, winding technology, sensors, and, manufacturing methods to obtain better and better performance.

Some of the competing types of motors are given below :

Table VI
Comparison of Motors

TYPES	POWER DENSITY	OVERLOAD CAPACITY	EFFICIENCY	SPEED / TORQUE CONTROL COMPLEXITY	MAINTAIN.	SYSTEM COST	COMMENTS
D.C.	↓	↑ ↑	↑	↓ ↓	↓ ↓	↓	Mature technology; Low cost; Periodical brush change: Bulky; Simple speed control
A.c. Induction	↓ ↓	↑ ↑	↓	↑ ↑	↑ ↑	↑ ↑	Robust; Reliable; Cheap motor but complex and costly control; Bulky
A.c. Switched Reluctance	↓	↑	↓	↑	↑	↑	New technology; Simple motor High torque ripple; High max. speed: Low control complexity
D.C. Brushless	↑ ↑	↑	↑ ↑	↑	↑ ↑	↑	New technology; Relatively expensive : P.M. tech requires improvement; V. Compact

For 2 wheeler applications where the power requirement is in the range 0.5 KW to 5 kW D.C., AC induction and DC Brushless motors can all be considered. Since 2/3 Wheeler applications require small bulk and weight, DC Brushless Permanent Magnet motors are ideally suited. However because of its relatively high cost, alternates may have to be pursued in the short term.

3. Controllers

The Controller in an EV takes the place of the accelerator and the carburetor of an I.C. Engine. It is used to control the Torque and Speed delivered by the Motor. Since both the Battery and Motor have specific, and sometimes, contradictory characteristics (e.g. the battery may not be able to deliver the very high currents at its terminal voltage, but, the motor might require these high currents, at a relatively low voltage, for the demanded acceleration). The controller is used to modify the input - output characteristics, and, allow the battery and the motor to perform optimally.

Controllers have changed considerably from the reliable, but crude, Resistance types of the early days to sophisticated Electronic systems of today. It is now possible to accurately forecast the optimum requirements of the battery and motor, from the demands made by the vehicle rider, and, allow the system to deliver its target performance in terms of acceleration, speed, and, range.

To match the differing requirements of diverse motor types, Controllers are now largely microprocessor based. These are generally embedded into ASICs (Application Specific Integrated Circuits) and are optimised for the type of motor, battery and vehicle in which it has to function. Complexities at this level does not have much cost penalty.

The low level circuitry drive Power Semiconductor devices which actually handle the large amounts of power which have to be controlled. Today's devices are universally MOSFETs (Metal Oxide Silicon Field Effect Transistor) or IGBTs (Insulated Gate Bipolar Transistors). The specific choice depends more on availability, and, the designers choice. Though devices for all relevant applications exist, they are relatively expensive. However, as with all other semiconductor devices in the past, sufficient volumes can drive prices down by an order of magnitude.

Since each motor requires a specific type of output circuitry, cost of controllers can vary considerably. The choice of motor and controller need to be taken together to allow for an optimum cost - performance trade off.

The technology of controllers is adequately advanced for immediate application into EVs.

4. Chargers

To replenish the energy lost by the battery during travel, it is necessary to charge them periodically. Since the battery, at present, is a poor substitute for petrol for long distance travel, it is imperative that the charging process is quick and simple.

In practical terms, the charger matches the available Mains voltage to the battery, and, controls the rate-of-charge so as to prevent damage to the cells whilst ensuring the shortest possible time to complete the process. As the technology of batteries progress, the process of charging is becoming complex, so much so, that, microprocessor based controls are likely to be used.

As the charger has to be periodically connected to Mains voltages, and, since it is likely to be used by lay persons without any knowledge of electrical engineering, it must be simple, foolproof, and safe to use.

In its most common form, the charger is likely to be a fixed device, either, at speciality areas like Roadside Charging Stations, or, in the house of the vehicle owner - the latter allowing the battery to be conveniently charged overnight. However it is entirely possible to carry the charger on the vehicle, whereby the vehicle owner need to find only the nearest electric outlet into which to attach his charger plug. It is also possible to incorporate the charger in the motor controller so that the size and weight can be reduced to an absolute minimum.

The problem of attaching chargers to Mains outlets has thrown up the question of adequacy of present day Plugs. Since the currents taken from these outlets would be considerable, to prevent accidents, a new set of standards will have to be laid down for these parts.

Some companies have developed Inductive systems whereby and contact with the Mains is totally obviated - One Public Utility is proposing to sink these at the kerbside, so that, all that the vehicle owner has to do is to park over the outlet to get his batteries charged.

However these products are still very expensive and, in the short term, more conventional methods will have to suffice.

For each of the above mentioned aggregates, the choice in the near term will be dictated by available technology for volume manufacture. However, pushed by a need for ever increasing capability, the viability of each technology will change fast. Whilst cost will remain a major criterion to judge suitability, volume manufacture, will, most likely, bring costs down essentially to material costs.

B. Performance Requirements

We have, till now, been considering the necessity of EVs, and, the status of requisite technology. Since EVs are unlikely to emulate the petrol vehicle in all respects, it is essential to set down realistic performance and cost targets to enable introduction of these vehicles in the shortest possible time.

As had been mentioned earlier, the major shortcoming of EVs is likely to be in the field of acceptable driving range. However, if we restrict this to the primary goal of Urban Commuting, we may be able to consider the target goals as below :-

Table VII
2 & 3 Wheeled Electric Vehicles - Performance Targets

Item	Mid Term Goal		Long Term Goal		Comments
	2W EV	3W EV	2W EV	3W EV	
Seating Capacity	2	4	2	4	
Payload (Kg.)	130	350	130	350	
GVW (Kg.)	250	850	220	800	
Speed (max./avg.)Kph	60/40	50/30	80/50	60/40	
Acceleration (m/s^2)	1.0	0.6	2.0	1.2	
Gradient (%)	15	12	20	18	
Range @ cruise (Km)	60	120	100	175	
Cost - Ex works (Rs.)	28,000/-	50,000/-	25,000/-	42,000/-	
Cost of Ownership (Rs/Km)	0.5	0.8	0.35	0.65	2W - 8,000 Km/yr. 3W - 36,000 Km/yr. Battery change- 2W - 1 every 3 years 3W - 1 every 2 years

C. Technology Inputs

Since little work has been done in India in the field of commercial EV technology, a significant amount of technology updation, at a fairly rapid pace, will have to be initiated.

However, with easy access to technology worldwide, the simplest and fastest route may be to acquire the relevant know-how from organisations experienced in this field, abroad. This will have to cover all the major aggregates discussed earlier.

Further, each of these technologies are of a specialised nature, and generally not within the expertise of Vehicle manufacturers of today. Vehicle manufacturers, who understand the design packaging and performance related parts of the product, will, therefore, have to depend on specialists to help in optimisation in each area of expertise. Hence these expert groups will have to acquire the necessary technology on their own and interact with the vehicle manufacturer to optimise the entire package.

A few of the more obvious technologies required are:

Table VIII
Technologies for Upgradation

Aggregates	Mid Term	Long Term	Comments
Batteries	• Advanced Lead Acid cells • Advanced packaging technology	• Advanced types of batteries • Advanced battery recycling technology	
Motors	• Manufacturing technology for D.C. Brushless motors (0.5=5 KW)	• Advanced cooling technologies for compact motors • Manufacturing technology for High Energy permanent magnets	
Controllers	• Manufacturing know-how for high reliability ASIC base controllers	→	
Charger	• Integrated chargers with advanced charge control	• Inductive chargers	

III. Groundwork Required for Introduction of EV's

The technology of EVs is going to be totally new in the country. Hence the infrastructure, in the public domain, to handle them will be non existent. To sell and operate these products, a major effort will have to be mounted in the following broad areas:-

A. Customer Awareness of:

1. Incentives to buy

* Low pollution/noise/vibration
* Low operating cost

* Low cost of ownership

2. **Manner to overcome deficiencies of**
   * Limited range
   * Large initial cost
   * Large maintenance cost every 2-3 years
3. **Manner to run and maintain new technology**

B. **Infrastructure Development in the areas of:-**

1. **Sale**
2. **Low interest finance** to negate the extra price of the vehicle.
3. **Maintenance facilities** for vehicles and their subsystems.
4. **Power for Battery Charging** requiring
   * New Power Plants
   * New Power Rates (who pays the new rates - individual owners or society?)
5. **Public facilities for battery charging/exchange**
6. **Disposal for used batteries**

C. **Government Inputs**

1. **Manner of financing infrastructure cost**
2. **Legislation to promote volume sales**
3. **Coordination between various agencies**
4. **Reviews of**
   * Product performance
   * Social benefits

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

Recommendations and Summary of Proceedings of the Third Session on Policy Issues

1. The pricing of conventional fuel like petrol and diesel should include external and invisible costs (environmental cost, national economic security cost etc.). The proposal of introducing pollution tax on vehicles based on conventional fuel should be examined.

2. Motor Vehicle Act should be amended so that fossil fuel vehicles may be banned in identified congested areas, near National Parks & Monuments Operation of non-polluting vehicles like Electric Vehicles at such place, should be made mandatory.

3. Formation of a consortium of concerned Ministries/Departments and the manufacturers of EVs, batteries and SPV modules etc. for facilitating a coordinated approach for the formulation of policies and other related issues, should be considered.

4. Provision of fiscal incentives such as exemption of excise duty and customs duty on batteries and other components/sub-components of Electric Vehicles (EVs), Exemption of excise duty on full Electric Vehicle, Battery pack for second set of battery and replacement set of battery, should be considered. Like other renewable energy equipments/systems, 100% depreciation for the purchasers of EVs should be allowed.

5. A scheme of providing concessional loan to the manufacturers of Electric Vehicles should be initiated.

6. Liberalised import of the latest technology, as regards the design, development and fabrication of Evs, should be facilitated and encouraged.

7. In the longer term there has to be gradual induction of zero emission vehicles powered by sustainable sources of energy like wind, solar energy, hydrogen, fuel cells, flywheels and ultracapacitors. Therefore, development works should be undertaken for the development of vehicles based on renewable sources of energy.

8. Continued support should be provided for R&D for development of EV and components and sub-components of EV both by the industry and the concerned Government Agencies/Ministries/ Departments.

9. Liberalised permit and other facilities to private operators for the operation of point-to-point service of BOVs alongwith exemption of passenger tax and permit fee should be allowed.

10. The Electric Vehicle operators should be allowed to charge the fare as per their cost of operation.

11. Concessional loans and other fiscal and financial incentives including 100% accelerated depreciation in the very first year for the purchase of EVs in transport fleet to Government/Semi Government/ Private organisation and cooperatives and also to private individuals should be provided.

12. Ministries such as Ministries of Railways, Tourism, Petroleum and Natural Gas, Steel, Atomic energy, Industry, Defence, Civil Aviation and Surface Transport alongwith their Public Sector Undertakings, State Electricity Boards and Electric Supply Corporations should be exhorted and encouraged to go in for the purchase of EVs in a coordinated and time-bound manner so that at least 10% of their fleet of vehicles consists of EVs. (by 2000 AD).

13. As charging in the off-peak hours in beneficial, concessional tariff for electricity in off-peak hours is recommended.

14. Energy conservation agencies, like Petroleum Conservation Research Association, Energy Management Centre, Ministry of Environment and Forests should also provide funds alongwith MNES as subsidy for purchase of EVs by the beneficiary.

15. Appropriate action has to be taken for publicity and awareness creation among the users about benefits of Electric Vehicles.

16. Exchange of information and personnel working in the field of EVs between India and technologically developed countries should be encouraged.

17. A task force consisting of representatives of MNES, DOE, Ministry of Environment and Forests, CSIR, Ministry of Surface Transport, Ministry of Industry and USAID should be formed to implement the recommendations.

Indo-US Workshop on Electronic/Electric Vehicles (EVs) - Technology & Policy Issues

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