Propulsion System Research and Development for Electric and Hybrid Vehicles

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The NASA Lewis Research Center is responsible for planning and implementing all propulsion system research and development work being supported under the Department of Energy's Electric and Hybrid Vehicle program. During the past 3 years the propulsion system project has grown until it now involves participation by approximately 30 industrial firms and universities through contracts and grants totaling over $7 million.

Present-day propulsion components and systems are unsuitable for a mass-produced consumer electric vehicle for two reasons. One is that available components are not designed for road service. As a result they are heavy and expensive and have relatively low efficiencies. In many cases basic performance data taken under conditions that are encountered in electric vehicle service are not available. The second reason is that the market for electric vehicles is not large enough, nor does it appear to be near-term enough, for manufacturers to invest funds in developing custom-built components for electric vehicles. Not only do the component manufacturers lack incentive to produce new products on their own, but the electric vehicle manufacturers do not have enough leverage with their suppliers to get the necessary technology development done. Therefore propulsion component and system technology development must be Government-supported for at least the near future in order to stimulate electric and hybrid vehicle commercialization.

The Lewis Research Center's approach to propulsion subsystem technology is as follows: For the next few years we will be providing engineering information to manufacturers that will assist them in building better electric vehicles. This will be done primarily through testing components now available to manufacturers and publishing data on their performance and through developing a component catalog that will give manufacturers a source of information on where to obtain propulsion components for their vehicles. Technology development in the near term will involve the development of improved components and propulsion subsystems based on existing technology. The philosophy here is to adapt the best existing techniques and designs to produce components specifically for electric and hybrid vehicle use. In the long term, advanced components and systems will be based on totally new technologies and will be quite different from those on the market today. The emphasis in all the development work is on cost, weight, and efficiency, with cost being the primary factor at present. This is because our studies show that if large-scale production of an electric vehicle were to take place using existing propulsion technology, as much as 50 percent of the cost of the vehicle to the consumer would be associated with the propulsion system. Therefore propulsion R&D offers a great opportunity for reducing the cost of electric and hybrid vehicles.

Component Characterization

Component characterization work is designed to provide engineering data to manufacturers on component performance and on important component–propulsion system interactions. Work is under way on motor and controller testing, transmission testing, and the study of battery–propulsion system interactions (fig. 1). The Eaton Corp. is the major contractor for motor, controller, and transmission testing and TRW, Inc., is conducting a battery testing project. Examples of the results of this work are shown in figures 2 and 3.

In figure 2 the efficiency in percent is plotted against the output in kilowatts for an electric vehicle traction motor operated in two different manners. The upper curve shows its performance on ripple-free dc electricity; the lower curve shows the way the motor performs when it is coupled with a conventional chopper type of dc motor controller. The ripple-free dc characteristic curve is typical of what an electric vehicle manufacturer obtained from a motor supplier's catalog; the chopped dc curve represents how the motor actually operates with a typical speed controller that would be used in a vehicle. Notice that in some areas, particularly at low power outputs, the difference between the two curves can be as much as 10 percentage points. This difference in efficiency results in a direct reduction of the range of the vehicle.

Figure 3 shows the performance of a three-speed automatic transmission from a compact car. Here the efficiency is plotted against the output speed under a range of conditions that are typical of what the transmission would see if it were operating in an electric vehicle. In an ordinary passenger car this transmission would have an efficiency approaching 90 percent, but in an electric vehicle it is operating sufficiently far from its optimum design point that the efficiency reaches a maximum of only about 80 percent. Again this results in a significant drop in range. Thus it is clearly important for the vehicle manufacturers to have performance data of this type. Unfortunately, this kind of data is not normally available from the component suppliers, and the vehicle manufacturer usually does not have the resources to provide it for himself.

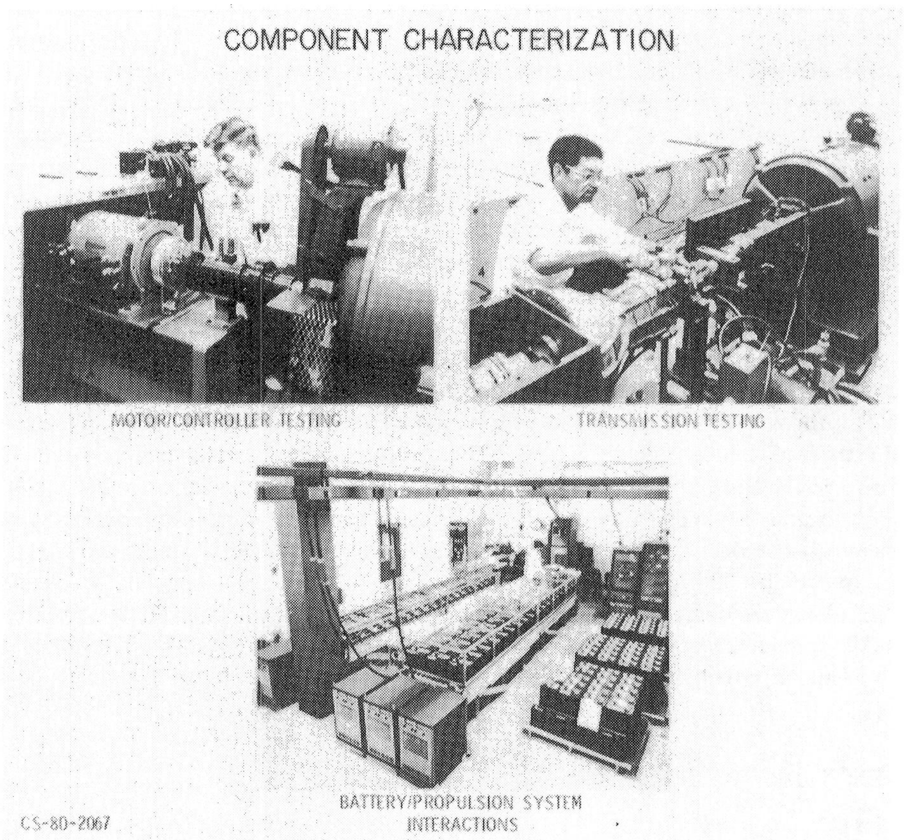

Figure 1

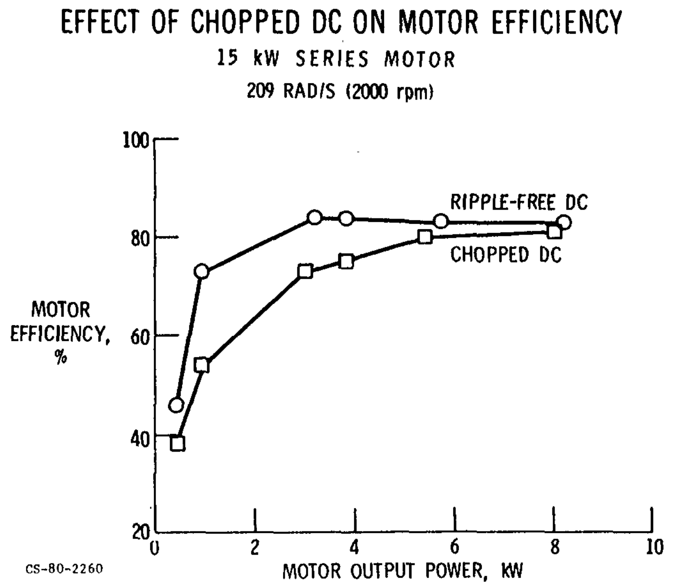

Figure 2

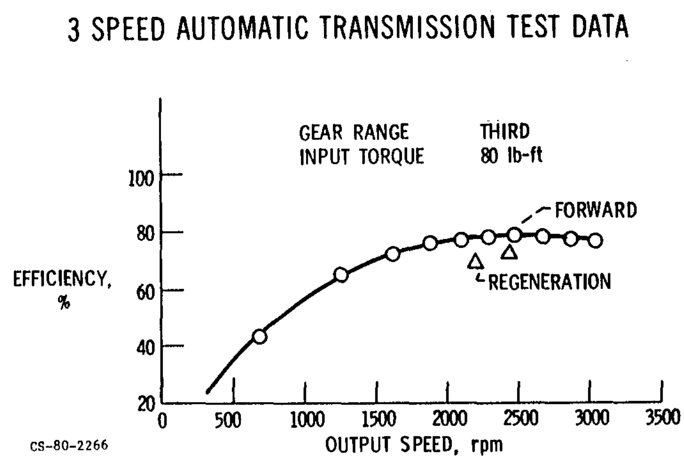

Figure 3

Component Development

The NASA Lewis technology development program is focused on three separate areas: One is power conditioning, which relates to the development of motor controllers. The second is the development of new traction motors of various types. The third involves transmissions designed specifically for electric and hybrid vehicles. Our long-term goal is to provide a propulsion system that has an efficiency approaching 80 percent under urban driving conditions and that will cost approximately $80 per kilowatt of rated power output and weigh about 7 kilograms per rated kilowatt. If we can reach these goals, the long-term effect would be a 20- to 30-percent reduction in the sticker price of an electric car and a 15- to 20-percent reduction in the overall life-cycle cost of that car to its owner.

Examples of our work on traction motor development are shown in figure 4. The improved motors that are being developed by AiResearch Manufacturing Co. and Virginia Polytechnic Institute use existing technology and are rather conventional in appearance and design. The advanced motors shown in the lower part of the figure are radically different. They emphasize the use of low-cost materials and novel design approaches that can result in smaller, lighter, and cheaper motors. The contractors for our advanced motor work are the General Electric Co., Westinghouse, and the Garrett Corporation's AiResearch Manufacturing Co. Other propulsion components presently under development are shown in figure 5. Motor controllers are being developed by the Chrysler Corp., General Electric, and Gould. The left photograph in the upper part of the figure shows a high-frequency (10-kHz) chopper type of controller that has been built and tested by Chrysler. It has an efficiency in excess of 90 percent over most of its operating range. The high frequency has a side benefit in that it tends to eliminate the characteristic unpleasant whine associated with the lower frequency choppers now used in controllers for electric vehicle motors. The right photograph shows a "breadboard" version of a motor controller being developed by General Electric that uses a new, lost-cost power transistor also under development at GE.

Continuously variable transmissions could be of great value not only to electric vehicles but to conventional automobiles as well, since they provide a way of improving the match between the motor output and the road load. Several promising designs are being investigated for electric and hybrid vehicle use, but it will be a number of years before they are available for installation in vehicles because of the difficult engineering problems that must be solved.

Propulsion System Development

NASA Lewis is also supporting the development of complete propulsion systems, for example, the ac drive being developed for Lewis by the Eaton Corp. (fig. 6). It consists of two major parts: One is

NEW PROPULSION COMPONENTS
TRACTION MOTORS

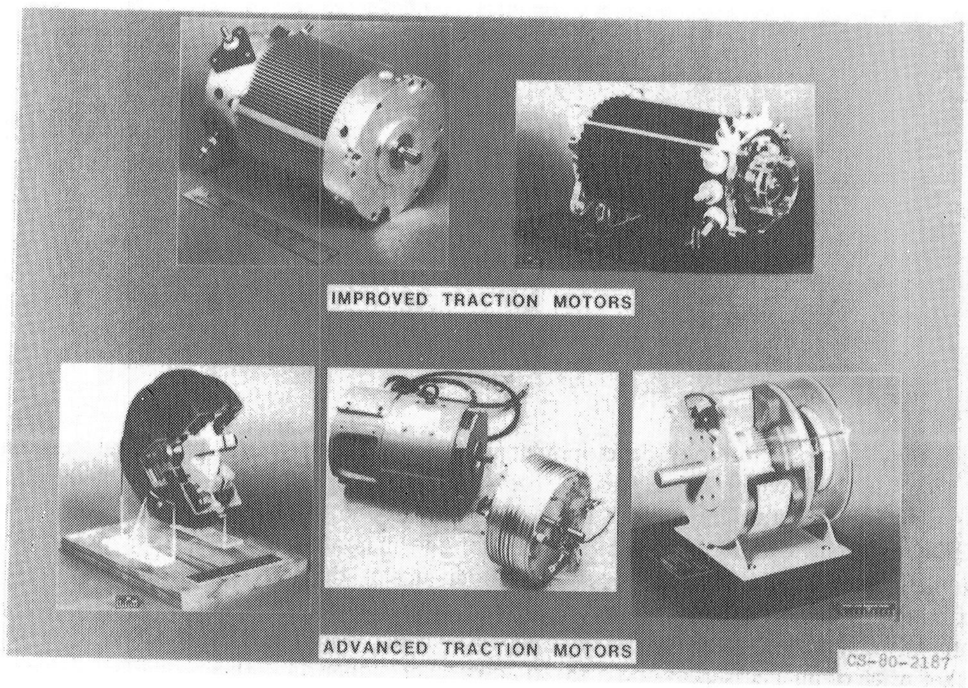

Figure 4

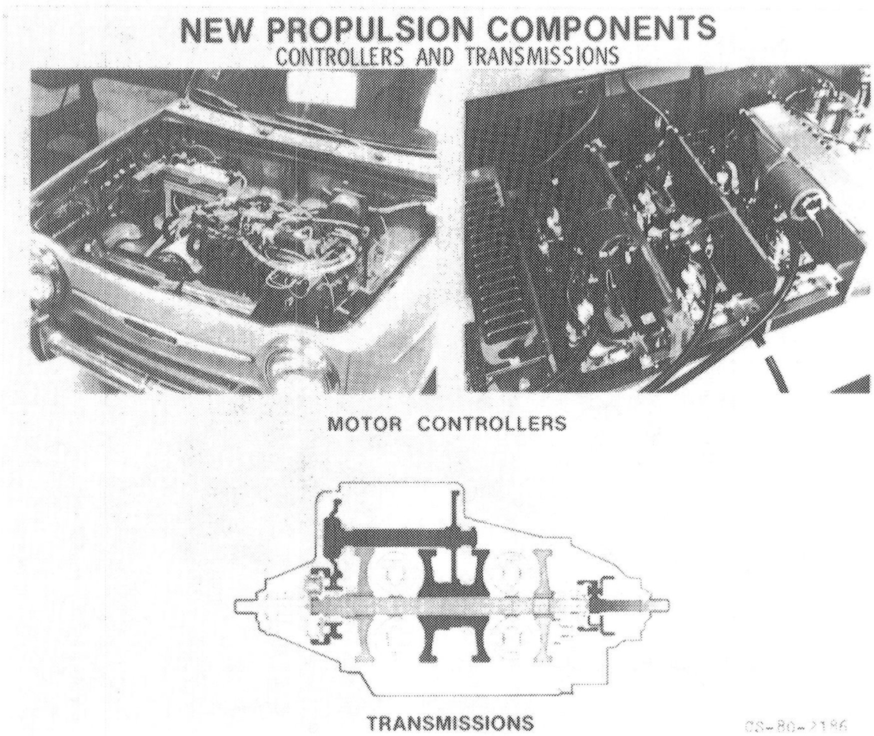

Figure 5

the ac motor, its controller, and a microprocessor or computer that controls the motor. The other is a two-speed, geared, automatic transaxle. The advantages of ac drives are well known. The motors are small and lightweight, require little maintenance, and lend themselves to mass production at low cost. The main disadvantage to an ac drive at present is the cost of the power transistors required for the inverter that controls the motor. The transaxle has been tested and has an efficiency of greater than 90 percent. An attractive feature of the transaxle is that it can also be used with a dc drive if it turns out that the transistor cost reductions do not come about as rapidly as they are expected to. The lower sketch in figure 6 shows an artist's conception of how the system would look if installed in a subcompact car of the Ford Fiesta size.

Propulsion system testing is expensive and difficult if it is done in a complete vehicle. This summer the Lewis Research Center will dedicate a new facility called the Road Load Simulator Facility. This unique laboratory is designed for testing electric and hybrid vehicle propulsion systems over a wide range of driving conditions in a variety of simulated vehicles at low cost and with high accuracy and reproducibility. We will be able to test propulsion subsystems under the conditions they would see in many kinds of vehicles, ranging from small subcompact cars to large delivery vans. A programmable driving-schedule controller will allow us to reproduce almost any type of traffic condition. The result will be accurate, convenient, cost-effective testing of electric and hybrid propulsion systems. The first system to be tested is shown in the lower right of the figure. It is the propulsion subsystem from the General Electric–Chrysler ETV-1 electric vehicle, which was developed for the Department of Energy and is described in the paper by Thomas Barber of the Jet Propulsion Laboratory.

In summary, the NASA Lewis Research Center expects four major benefits to accrue from our propulsion system R&D work. First, we will provide current vehicle manufacturers with engineering design data and new propulsion components and systems that will assist them in producing better vehicles. Second, we will improve the technology base from which vehicle manufacturers can draw in the future in designing commercial vehicles. Third, we expect to help reduce the near-term R&D

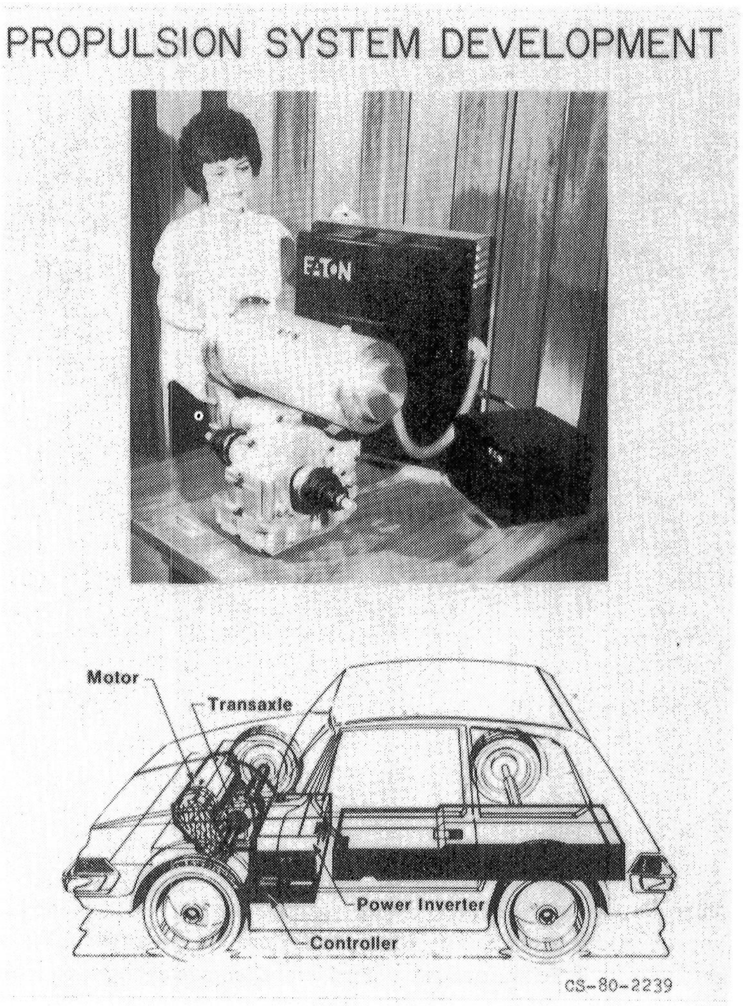

Figure 6

investment required by industry while the potential market is uncertain. And finally, we expect to significantly reduce the purchase price and ownership cost of mass-produced electric and hybrid vehicles.

Since we are dealing in research and development work that is associated fairly closely with a potential commercial product and are attempting to stimulate an earlier commercialization of that product, we believe that new approaches are going to be required in our R&D contracts. We feel that it will be necessary to provide incentives to industry in the form of cost and risk sharing at times when market conditions make R&D investment by industry on their own unlikely. These incentives might take the form of exclusivity in data and patent rights in return for which we would expect industry to pay back the Government's investment if the projects are successful. This is something that is already being done in our aeronautics program. Furthermore we will have to protect the taxpayers' interests by insisting on "march in" rights to have others continue the work if the company decides to drop the project and a market still appears to exist. We are presently discussing an approach to this type of procurement activity with the Department of Energy for possible use in future procurements.

Concluding Remarks

The electric vehicle was once a major factor in our Nation's transportation system. Today we are seeing rebirth of the electric vehicle industry based on conversions of conventional automobiles and light trucks and a few purpose-built electric vehicles with somewhat limited performance. By the mid-1980's, however, we expect this industry to grow to the point where mass-produced, carefully engineered electric vehicles with high consumer appeal are going to begin to appear on the roads.