Electric Vehicle Specifications for Competitive Marketing

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Abstract

This paper describes General Motors studies of thirty years ago, the conclusions of which appear to the author, to still be appropriate today. The paper further relates the conclusion of these studies to the design and construction of electric and hybrid electric vehicles since that time, at present and in the future.

That conclusion was (and still is) that electric automobiles cannot be consumer competitive practically, socially, or economically unless something changes, such as the available technology, or the consumers expectations, or the economic environment.

The truth of the matter is that given any electric vehicle design, styling, structure and any set of amenities, substituting an equivalent performing internal combustion engine/transmission, with appropriate environmental modifications, the results will be a more competitive and marketable product than any electric or hybrid electric combination foreseeable in the past or present.

The conclusion of this paper is that, it will not be possible for at least twenty years after the decision is made, and until some $20 billion in resources are available, to design an electrochemical engine to power a consumer competitive automobile that people would buy. Even so, the risk of failure is high and the cost estimates are optimistic.

Introduction and Background

In response to governmental concerns about the role of automotive emissions in environmental pollution, and the potential of alternatives to the internal combustion engine during the nineteen sixties, studies were conducted at General Motors on electric vehicle batteries, electrochemical engines, electric propulsion motors, hybrid electric/ICE configurations, electronic controls and the design of vehicles which would serve consumers, accommodate the components and be marketable.

Those General Motors, confidential studies (Ref. 1-3) led to the fabrication and limited production of several different prototype vehicles, continuing research at GMR and additional electric and hybrid electric vehicles at Minicars Inc. While several papers were published (Ref. 4-7), several important conclusions about the design and marketing of alternative fuel vehicles and their power trains remain tacitly confidential at GM still today.

This paper is intended to describe those studies of thirty years ago, the conclusions which appear to the author, still appropriate today. It will also relate the sudies' conclusions to the design and construction of alternate fuel (primarily electric and hybrid electric) vehicles since that time, at the present and in the future.

Discussion

Electric vehicles have been and are feasible, practical and serve many transport functions worldwide. Within the limitations of current state-of-the-art batteries, electric vehicles are easy to design to serve a specified function. However, it was not possible in 1968, it is not possible today and it will not be possible for at least twenty years after the decision is made and resources are available, to design an automobile, that people would want to buy with an electric engine.

That is not to say that an electric car cannot be designed to meet what people claim they would find acceptable, or what they perceive to be acceptable. It means that an internal combustion engine can be modified to meet almost any social requirement with substantially more consumer value and higher benefit to cost ratio than a battery electric engine.

The truth of the matter is that given any electric vehicle design, styling, structure and any set of amenities, substituting an equivalent performing internal combustion engine/transmission, with appropriate environmental modifications, will result in a more competitive and marketable product than any electric or hybrid electric combination foreseeable in the past or present.

Notwithstanding any legislative or EPA mandate it is inconceivable that consumers will accept or consider on its merits, an electric or hybrid electric power-plant given a real social and/or economic (rather than wishful) choice. In other words, even if the strictest EPA rules could be enforced, the restricted flexibility and performance of currently available electric batteries and the lack of necessary infra-structure, would preclude consumers buying and continuing to use them in any quantity.

That is not to say, that special circumstance local transportation vehicles such as in Zermatt, Switzerland, or in Long Beach, California, USA, may not enhance the environment by the addition and private use of electric vehicles, or that electric golf carts and factory forklifts and travelers are not competitive.

On the other hand, true commercial transportation experiments such as the 26 identical 70 passenger electric and diesel buses built in 1982 for the limited access 16th Street Mall in Denver, Colorado and sponsored by their Regional Transportation District (ref 10), have after ten years succumbed to the economies of an all diesel fleet.

Even in Europe, where the price of gasoline includes more than two dollars a gallon in taxes, private electric vehicles have little competitive consumer appeal.

Current reported research efforts make clear that the limitations foreseen in the sixties have not been adequately addressed and as then, are twenty years from being resolved, while the consumer's appetite for power and flexibility is undiminished.

The heart of the problem is the automotive consumer's expectations and requirements for power and energy, and the available electric power plant's ability to compete with the developed capacity of the ICE/gasoline power plant on a horsepower/pound and horsepower-hour/pound basis. There are wide ranges of component and system performance (results and claims), but the magnitude of the problem is clear enough. To illustrate, and for the sake of comparison, gross "ball park" estimates are used in the following discussion:

From a rotating power point of view,

1. A typical ICE delivers one hundred horsepower and weighs 500 pounds or 5 pounds per horsepower,;

2. A conventional DC motor weighs about 400 pounds per 100 horsepower or 4 pounds per horsepower; while

3. A high performance inverter/AC electric motor (Ref. 8) weighs 200 pounds and delivers about 100 horsepower or 2 horsepower per pound.

Therefore except for cost, power isn't the problem.

The problem is the horsepower and horsepower-hour per pound of battery as compared to gasoline.

1. A lead acid battery can supply about 1/10 horsepower per pound and about 1/100 horsepower-hour per pound; as compared to

2. The 20 horsepower-hours per gallon (7 pounds) of gasoline (converted) or 3 horsepower-hours per pound;

3. An expensive (limited recharging) silver zinc battery can deliver 1/20 horsepower-hour per pound, four times as much as lead acid but only 1/60 as much as gasoline.

The point is that the disparity is a factor of 100, and several 20% component improvements, or even several two to 1 component improvements or breakthroughs won't solve the battery problem.

To understand the magnitude of the difference, think about the fact that with your auto's 500 pound engine and transmission and two gallons (15 pounds) of gasoline you can travel 60 miles. To do the same thing with an electric power plant the vehicle weight would increase by at least (60 x 15 = 900) 1000 pounds. And it takes another 1000 pounds for each additional 60 miles range.

On that basis, it was (and is) clear that electric automobiles cannot be competitive practically, socially, or economically unless something changes, such as the available technology, or the consumer's expectations, or the economic environment. That was the situation when I left GM in 1968.

General Motors did not release these conclusions and still offers hope to Government demands and consumer wishful thinking by developing and demonstrating 20% component improvements, and combining them into a non-competitive product such as the "Impulse" prototype vehicle.

No one considers that if the "Impulse" were fitted with a gas tank instead of its battery, and a high fuel economy, high performance, low emission Honda Vetec engine with an electric preheated low emission catalytic converter, the vehicle would be able to be driven across all the land areas of and around the world, without refueling and with a minimum of emissions.

In the last twenty years, much similar research effort sponsored by the US Department of Energy and other commercial interests has gone into reducing the weight and power consumption of developmental electric cars. From a practical point of view these are the only things that can be done, but are useless in the larger framework of developing competitive electric vehicles.

This is because the "right" thing to do is to develop an electrochemical engine, and that is a job of monumental proportions requiring skills, talents, resources and ten to twenty billion dollars, none of which is readily available. Furthermore, there are many who consider the project controversial and readily challenged on practical and safety grounds.

An electrochemical engine delivering 10 to twenty times the energy/pound of the lead acid battery was begun at General Motors in the early 1960's and several high energy battery projects were initiated at the same time elsewhere at GM, at Ford and at Government Labs. Ford at least, has been persistent with its sodium sulfur battery and perhaps is further along than anyone. But, recent indications are that the functional application and use problems foreseen in the sixties are again meeting with public and management resistance.

That resistance stems from the fact that all high energy batteries involve very energetic, corrosive, toxic, high temperature molten chemicals such as lithium, chlorine, sodium, iodine, etc. This means they are difficult to contain, control, isolate, insulate and package and they bring up the specter of mass contamination and distruction with every accident. And to some extent it is all true, which of course is why such a project is likely to be so expensive.

Conclusions

The 1960's decision to put the electrochemical engine and high energy battery projects on the "back burner" has precluded the development of a competitive electric car.

We CAN be certain that the path of science into the future will be loaded as always with twists, turns and cut-backs. But in moving forward, perhaps we should spend more effort in researching how to change consumers expectations, or effecting change by economic dis-incentives, or by taxing offensive polluters, or by producing ultra low emission ICE vehicles.

References

1. "A Market Study of Electrically Propelled Automobiles and Motor Trucks", D. Friedman, GM Confidential, September 1966

2. "Current Results of a Contiuing Study of the Commercial Prospects for Electric Vehicles", D. Friedman, GM Confidential, June 1967

3. "Development of High Performance Electric Drive System", P. Agarwal, GM Confidential, August 1962

4. "Lightweight Lithium-Chlorine Battery", S.J. Werth, AIAA, September 1964

5. "The Correlative Advantages of Lunar and Terrestrial Vehicle and Power Train Research", D. Friedman, SAE, January 1966

6. "Engineering Requirements for Electric Vehicle Power Trains", D. Friedman, IECEC - August 1967

7. "An Electric Automobile Power Plant Survey", D. Friedman, IEEE - March 1968

8. "The Minicar Mass Transit System - an Electric and/or Hybrid Electric Car for Urban Center Use", D. Friedman, Minicars, Inc., U.S. Department of Transportation, Urban Mass Transportation Administration - June 1970

9. Electric Propulsion Motor Patent, No. 3,323,032 (1963)

10. Electric and Diesel Transit Buses for the Denver Regional Transportation District, Colorado, USA 1982