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The Delco Remy Electric Vehicle "Quick Change Battery" Concept

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ABSTRACT

The Quick Change (QC) Geo Metro electric vehicle was built for Delco Remy (DR) to explore the feasibility of quick battery exchange as an alternative to on-board battery recharging. Quick change is a process in which the whole battery is mechanically removed from the car and replaced with a fully charged battery. Although the infrastructure of quick change has not yet been addressed, an automated battery exchange station is envisioned that would be similar to present day automatic car washes. In this battery exchange station a "hands free" battery exchange process could be performed in less than one minute with the aid of automated battery removal and insertion mechanisms. The removed battery packs would then be charged slowly during non-peak hours by trained battery maintenance personnel. The quick "refueling" provided by such a facility may help gain consumer acceptance for electric vehicles (EV) by enabling an EV to drive from Los Angeles to San Francisco (with sufficient installed infrastructure) without a technological breakthrough in batteries.

This report describes the methodology of the quick change, describes the Phase I and Phase II conversion of the Geo Metro from gasoline to electric, and provides recommendations for future performance and safety enhancements. In Phases II and III of the project, the QC Geo Metro will be used as mule vehicle for the evaluation of two off the shelf drivetrains (DC brush and AC induction). At the end of Phase III, a final evaluation will be performed to access the feasibility of quick change as a means of refueling and determine if quick change should be explored further.

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1. BACKGROUND

Electric cars today have two main shortcomings: low range and long recharge times. Until a solution to these obstacles is found, electric cars will have difficulty competing with internal combustion engine (ICE) vehicles for consumer acceptance. With present technology, ICE vehicles are capable of driving over 300 miles on a single tank of gasoline and can be refilled in under five minutes. The range limitations of EVs are directly related to the relative energy densities of the two energy storage media (when burned in an efficient engine, gasoline has a specific energy of 5000 Wh/kg whereas near term electric vehicle (EV) batteries have only 35 Wh/kg).

Although much effort is being spent on developing advanced high energy batteries, it is anticipated that these new batteries will still require recharge times of two to eight hours. Because the customer is accustomed to a five minute gasoline stop, he may perceive these recharge times as being long and inconvenient. High power quick charging has been proposed as an alternative to long recharge times. However, charging a battery in less than 15 minutes reduces battery life, does not fully charge the battery, is very inefficient, and causes excessive heating in the battery. There are also electric utility infrastructure problems associated with quick charging. Quick charge filling stations must either be connected to high power lines, or have expensive on-site energy storage. To prevent overload of the utility grid, stations without on-site energy storage will most likely have limitations on quick charges during peak demand hours, greatly curtailing their usefulness.

"*Quick change*" (QC) battery packs may be a possible solution to this problem. If QC batteries could be removed from a car and replaced in less in one minute, the discharged pack would then be allowed to slowly recharge off-board during non-peak hours. This type of system would increase customer acceptance by allowing the customer to "refuel" the electric vehicle as quickly as an ICE vehicle (> 1 MW refueling rate). Recharging the batteries off peak would benefit the utility companies by helping to distribute the power demand. Quick battery exchange would also favor long battery life because the batteries would be allowed to recharge properly (> 8 hours) in an EV service station.

2. QUICK CHANGE BATTERY VISION

Designing an electric car with a quick battery exchange requires innovation and forward thinking in the area of infrastructure; however, there is ample precedent for quick change in battery operated toys and cordless power tools. Despite this, the large size of an EV battery pack introduces handling and storage problems which will require innovation and infrastructure. Quick battery change facilities could be established in conjunction with gasoline service stations (an established infrastructure). The automatic battery exchange could be performed in the same manner as present day automatic car washes. The quick change car drives up to a conveyer belt and is automatically driven to the battery removal station, located under the station floor. An automated battery removal mechanism rises from the floor, locates the battery pack in the car and removes it. All battery power cables and instrumentation are automatically disconnected through set of spring-loaded contacts. The battery is removed from the car and placed into a charging slot, similar to a cassette holder. Another robot removes a fully charged battery pack from a charging slot and inserts it into the car.

The batteries would most likely be leased from the battery company by the vehicle owner and the owner would pay a monthly fee for use of the battery. If this system could be implemented, the advantages would include:

- enabling EVs to be competitive with ICE vehicles without a battery breakthrough
- eliminating customer worry regarding battery replacement costs and maintenance
- enabling EVs to have unlimited range (providing that refueling stations are located as frequently as gas stations)
- improving battery life
- allowing EV's to be refueled in less than one minute
- be performed safely and automatically

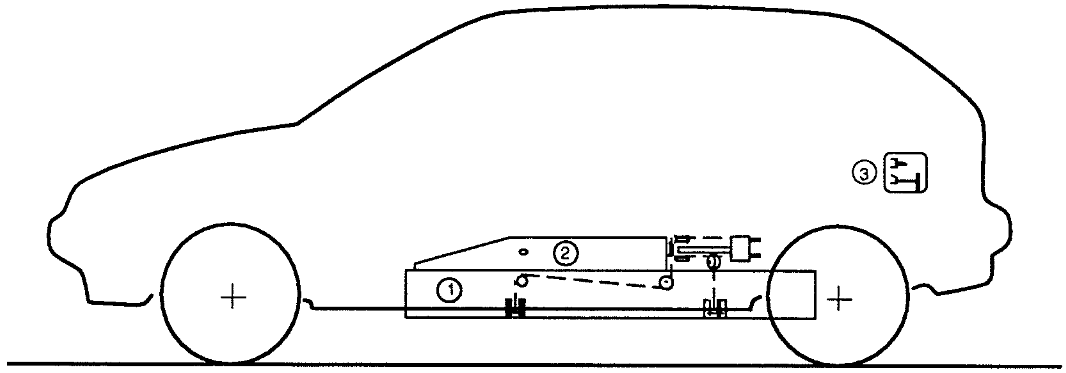
Although quick change battery infrastructure is beyond the scope of this document, many issues involving infrastructure would need to be addressed if this system were to be adopted. Some of these infrastructure issues are:

- Who owns the battery (the battery company, the service station, or the vehicle manufacturer)?
- Who maintains the battery?
- How is the replacement cost of the battery amortized in the battery lease?
- How is battery abuse prevented?
- How are the battery packs dimensions and exchange methods standardized for all vehicle manufacturers?

3. INTRODUCTION

The Quick Change Geo Metro was built by Ely Schless of Brand X Special Effects for Delco Remy as a proof-of-concept quick change electric commuter car (Diagram 1.). While the QC Geo Metro was designed to evaluate the feasibility of quick change, the vehicle is also a propulsion system test bed for comparing two off-the-shelf vehicle powertrains and three different battery configurations. The program is divided into three phases, each phase corresponding to a different powertrain and battery combination. In all three phases, the battery box location and outer dimensions will remain unchanged. Although battery exchange and off-board charging will be performed, an on-board charger will be available in Phase II and Phase III. This document describes the Phase I and Phase II vehicle conversion and the test results from the two Phases.

Phase I encompassed three months, starting in March 1993 and concluding in May. The Phase I powertrain consisted of a DC drive system with a Curtis PMC controller (120 V, 400 A, 48 kW peak power) and an Advanced DC series-wound brush motor (20 HP continuous rating, 90 HP peak). The DC drive motor was coupled to the input shaft of the stock manual five speed transmission through the stock clutch and flywheel assembly. The battery pack consisted of 24 Delco Freedom 50 maintenance free batteries, configured in two 120-V strings in parallel.



① BATTERY PACK / RECEIVER BOX
② HYDRAULIC LIFTING ACTUATOR
③ OPERATOR'S CONTROLS

Diagram 1. Quick Change Geo Metro

Phase II began in June and will end in September of 1993. The Phase II powertrain configuration consists of the Phase I drivetrain (Curtis controller and the Advanced DC motor). The Freedom 50 batteries, however, were replaced with thirty 12-V gas recombinant "Impact" Lead Acid batteries arranged with three strings in parallel, resulting in a system voltage of 120-V. In Phase II, a 2 kW on-board charger was installed for on-board convenience charging.

Phase III will begin in October 1993 and last for one year. In Phase III, the manual transmission and DC drivetrain will be removed and the AC-100 (100 kW AC induction drivetrain by AC Propulsion) will be installed. The Delco gas recombinant Lead Acid batteries will be reconfigured from three 120-V strings to one 312-V string, composed of 26 batteries in series. The AC-100 contains an integrated charger located in the inverter that will be used for convenience charging.

Design reviews will be performed by AeroVironment and Delco Remy after the completion of Phases II and III. The results of these reviews will produce safety and vehicle enhancement recommendations to be implemented either on this vehicle or a future follow-on vehicle, if the battery exchange concept proves to be feasible.

4. METRO ELECTRIC CONVERSION

4.1 Chassis Selection

The QC Geo Metro is an energy efficient two passenger vehicle that can be used for personal commuting or utility applications. The 1992 Geo Metro sedan was chosen because it had the highest fuel economy, lowest weight, and lowest aerodynamic drag available in the General Motors' fleet today. The quick change battery was packaged below the vehicle. In order to package the battery pack in one unit under the floor pan, alterations to the metro unibody structure, rear suspension and transaxle mounting were made. Although the original Metro was designed to be a four passenger commuter vehicle, the QC Geo Metro was modified to be a two passenger utility vehicle with a large cargo area.

4.2 Removal of I.C.E. Components

The I.C.E. engine/drivetrain components were removed from the Metro and the electric components and drivetrain elements were installed. During the course of the conversion, many of the existing drivetrain components which were removed caused other subsystems to be no longer functional. For example, the compressor for the air conditioner was removed with the engine, consequently, air conditioning is not available. Heating and air conditioning can be provided in an electric vehicle with electric compressors and pumps; however, climate control is not needed to fulfill the mission of this vehicle therefore it was decided not to replace the HVAC systems.

Listed below are the original equipment components that were removed during the conversion process.

1. Internal combustion engine
2. Fuel system (fuel tank, fuel lines, and hoses)
3. Cooling system (radiator, heater core, and hoses)
4. Wire harness for I.C.E. engine
5. Exhaust system and hangers
6. HVAC (heat exchangers, compressor, hoses, descant can, and freon R-12)
7. Rear seats

The transmission was retained for use with both the DC and AC drivelines. The DC driveline will retain the stock five speed transmission and the clutch. The AC driveline, however, only requires one gear and therefore only second gear will be enabled.

4.3 Battery Box

The rectangular battery box was constructed from 0.100" hot rolled steel (12 gage). Two webs inside the box provide torsional rigidity and provide lateral battery support by dividing the box into three compartments (Fig. 1). Four lifting hooks were welded on to the outside of the box and serve as the quick change lifting cables attachment points (Fig. 2).