

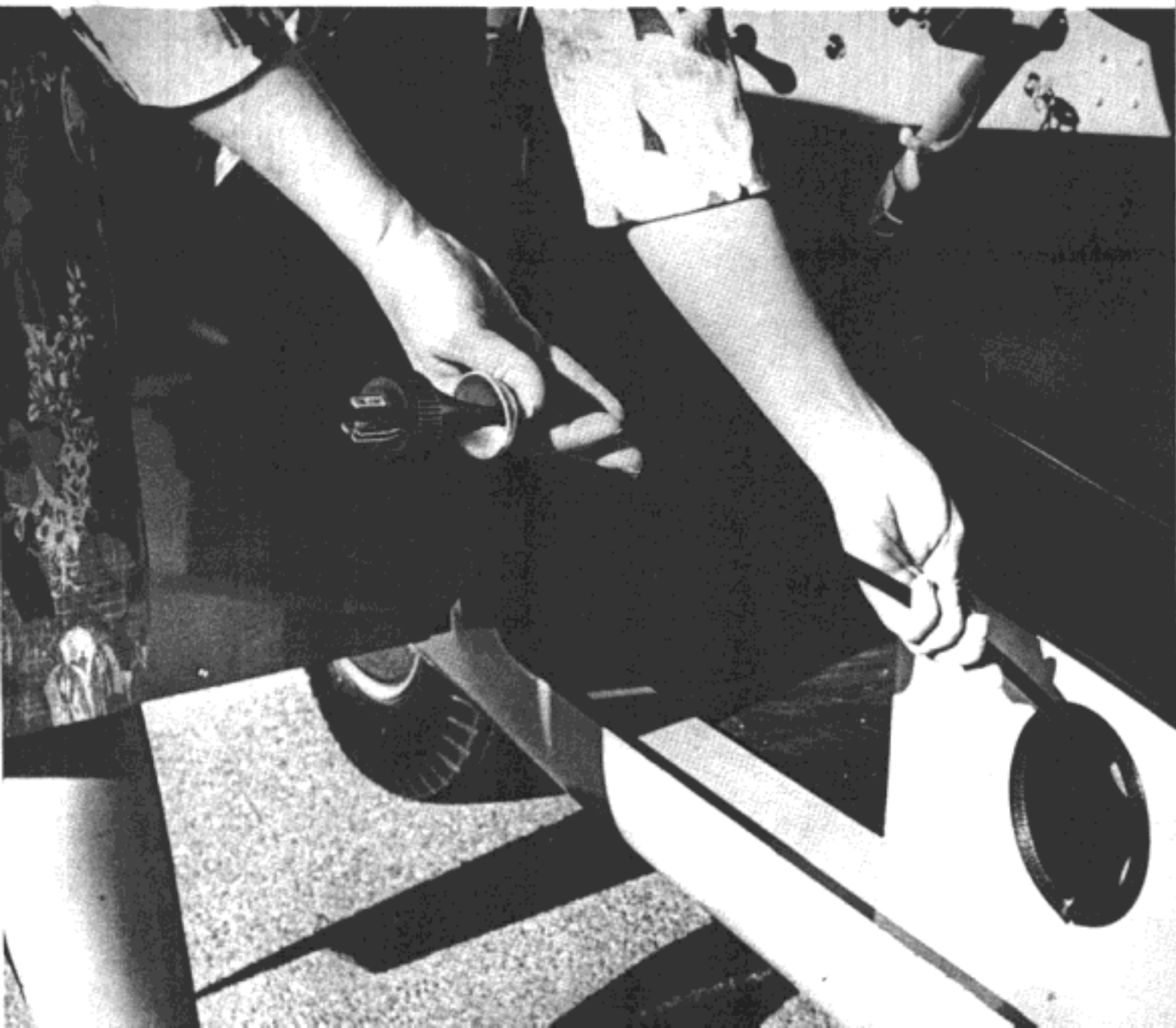
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THREE NEW DEVELOPMENTAL ELECTRIC CARS SHOW MAJOR DIFFERENCES 20

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Power sources used reveal varying degrees of sophistication but all three vehicles still suffer from operating range and refueling time limitations.

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Different approaches are adopted in the three electric cars recently developed by Ford, General Electric, and Electric Fuel Propulsion. This is evident in the varying performance abilities, and the different power systems used, propulsion control methods, and vehicle sizes. The Ford version, called the Comuta (Fig. 1), is the most spartan of the group, having minimum size, speed, and range. GE's subcompact town car, the Delta (Fig. 2), represents the next step-up in size and performance and the Mars 11 electric car, developed by Electric Fuel Propulsion Inc. (shown in Fig. 3), is the most commodious of the lot.

Ford Comuta

Designed and built in a little over a year's time, the electric car developed by Ford of Britain was sized to occupy minimum road and parking space and constructed to have low initial and running costs. To meet the size requirements the Comuta is dimensioned with an 80-in. overall length and a 49.5-in. width. Height is 56 in. Its short length permits end-on parking within the width of existing street parking spaces, and its narrow width allows three Comu-

tas to park this way in the space normally occupied by a standard-sized U.S. passenger car. There is room enough inside for two adults in front and two children in back.

Power for this little vehicle is supplied by two series wound, 24-v, d-c motors, each driving one rear wheel. These 39-lb motors are uprated versions of motors used for aircraft auxiliaries and can produce a maximum of 5 hp each. As they are connected in series, the car has a 48-v electrical system, the power source being four conventional 12-v lead-acid batteries.

Since starting load current would be excessive if full battery voltage were to be initially applied to the d-c motors, an electronic chopper is used to provide pulse control of the motors. The chopper uses thyristors, which are semiconductor devices capable of operating as high speed switches, to apply battery voltage to the motor in pulses, thus reducing the effective voltage during the starting period. The Comuta controller employs a fixed "on" pulse of 1.2-msec duration which can be applied at frequencies ranging between 30 and 780 pulses/sec. In the starting condition a low frequency of

application is used and as speed increases the frequency is increased until the motors receive battery voltage almost continuously. The ratio of "on" to total periods is controlled by the accelerator pedal.

When the key switch of the Comuta is turned on the vehicle is ready to operate. The direction switch may then be moved from neutral to either the forward or reverse position. At the first movement of the accelerator pedal either the "forward" or "reverse" solenoid is energized according to the direction switch position and the appropriate contacts are closed to complete the power circuit. Once sufficient road speed is achieved at the condition of maximum accelerator pedal depression, as determined by the system's logic unit, an override contactor bypasses the thyristors to connect the motor directly to the batteries.

Measured acceleration time from standstill to 30 mph varies from approximately 12 sec with fully charged batteries to about 15 sec as the batteries approach exhaustion. Acceleration from 30 to 40 mph, the Comuta's top running speed, is quite slow even with the motor connected directly across the battery, so the time exposed to danger while passing is longer than would be desirable in a production car.

Gross vehicle weight is 1550 lb, about 1/4 of which is taken by the batteries. With this weight, endurance runs have shown the range to be 37.5 miles at 25 mph. Each energy-consuming acceleration lowers the attainable range.

Since it was not practical to size

the motor and control to withstand accelerating torques continuously, there is a warning light for motor over-temperature. Also, a battery disconnect switch is provided to afford positive means of removing driving power from the wheels in case of extreme drive failure.

Cab heating in the Comuta uses power lost in the motors and controls and is only marginal. The system exhibits an average 4 F per minute rise of cab temperature to 67 F over a 37 F ambient.

The chassis is fabricated of 1/16-in. sheet steel. The front cross-rib carries the steering unit, brake and control pedals, shock absorbers, two body mounts, and the ventilation ducts. The front suspension consists of two leading arms with rubber springs, mounted to two angled ribs.

Current effort on the Comuta is aimed at reducing its overall weight to increase its driving range.

Delta vehicle

The GE experimental electric car uses the hybrid battery concept to solve the limited drain rate problem for most vehicle applications. The lead-acid battery used on the Delta has a limited drain rate capability and cannot sustain the acceleration and high speed power needed for vehicles of 2000+ lb weight and 50+ mph top speed. However, with the hybrid battery concept, a nickel-cadmium battery capable of very high discharge rate is paralleled through electronic circuitry to the main battery.



FIG. 1 Comuta electric car developed by Ford of Britain is very limited in range, 37.5 miles at a steady 25 mph being a simple performance, and the top speed is 40 mph. This 1550-lb vehicle, 384 lb of which is battery weight, is able to transport two adults and two children.



FIG. 2 Delta electric car developed by General Electric uses the hybrid lead-acid, nickel cadmium battery concept to attain a top speed of 55 mph and a range of 100-120 miles at a steady 30 mph. The vehicle weighs 2300 lb and can carry two adults plus two or three children.

The circuitry automatically senses the drain rate and brings on and gradually increases the current delivery from the nickel-cadmium booster as the load increases beyond the economical capability of the main battery. The control circuit also automatically recharges the booster unit when it is not delivering current. The recharge is cut back to a trickle level once the booster is recharged and is cut off when the vehicle's key is turned off. Fig. 4 shows the effect of using this system on a Delta-size vehicle under steady cruise conditions and also under a 4 stops/ mile 'town duty cycle. It can be seen that, due to its charging inefficiency,



FIG 3 **MARS 11 electric car** developed by Electric Fuel Propulsion uses tripolar, lead-cobalt cell design in four 30V, 290-amp-hr batteries to propel its 4260-lb weight. Regenerative braking is also used to help attain a single-charge range of 70-120 miles, Top speed is 60 mph.

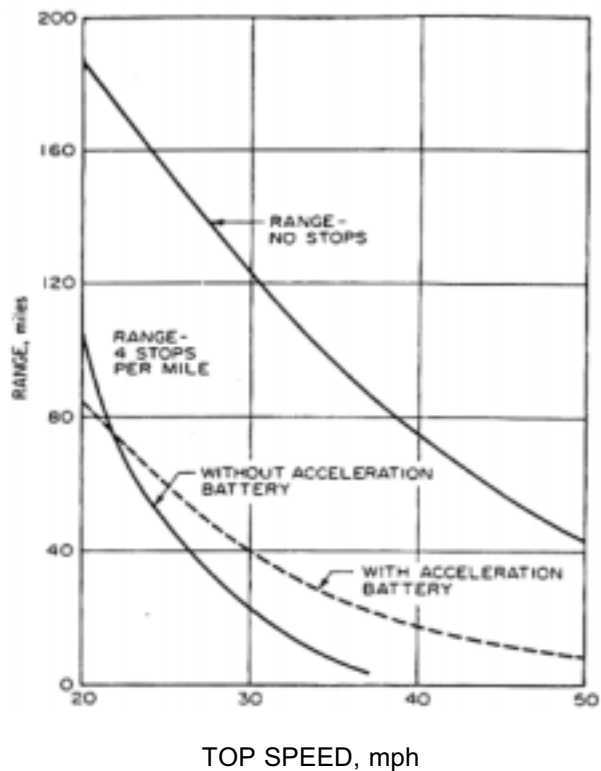


FIG. 4 Computed range chart of a Delta-size vehicle under no-stop driving conditions and also under a 4-stops-per-mile condition. Nickel-

cadmium booster battery used in this car is seen to improve the attainable range under the latter condition at higher between-stop speeds.

Booster battery increase range at high speeds, with four stops per mile.

the booster battery does not aid the cruising range or very low speed town operation, but the range increase with higher speeds between stops is apparent.

The main battery used in this system must have a sufficient power delivery rate to propel the vehicle at continued steady cruise up to its maximum recommended speed. The booster unit, while providing power peaks for occasional hill climbing, will not be re

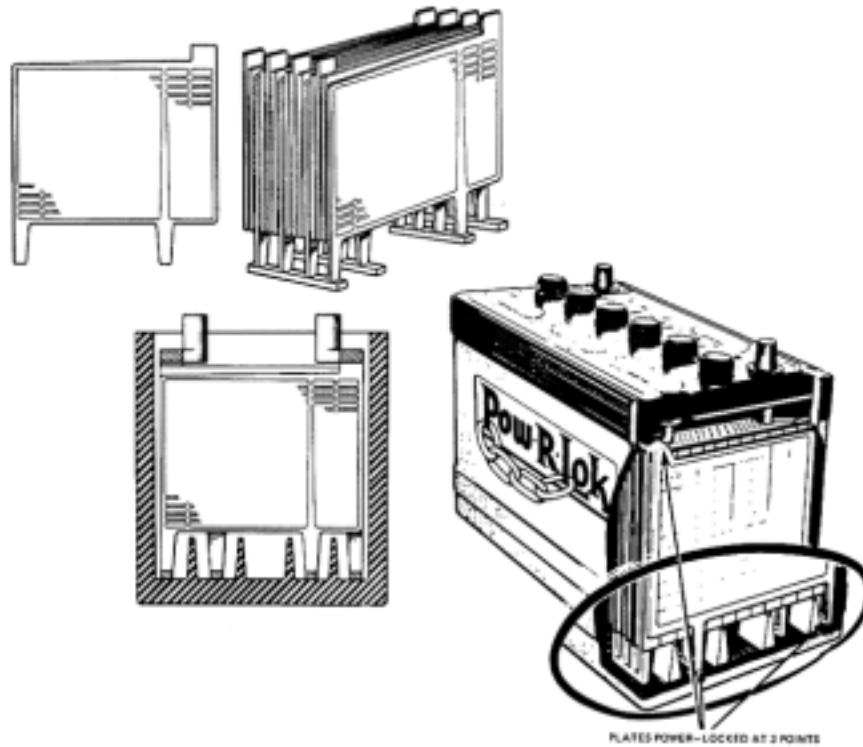
charged during cruising unless the main battery's output exceeds the cruising rate power demand. The Delta uses an experimental, 72-v, lead-acid main battery weighing 864 lb.

The Delta's motor is a 10.9 hp, d-c series type which is also controlled by an electronic chopper. It gives the vehicle a top speed of 55 mph and a maximum acceleration rate of 6 sec from 0-30 mph. Cruising steadily at 30 mph the Delta's range is 100-120

miles. This drops to 50-60 miles at a 40-mph cruise speed.

A 30-amp, on-board, solid-state charger unit provides an 8-10 hr recharge period. A stationary charger can give an 807c charge in 2-3 hr.

Operating cost of the vehicle would be 1.00/mile at a steady 30-mph speed, and 3.20/mile at 50 mph. These figures are for a standard lead-acid main battery and include the battery amortization. Power costs are assumed to be 1.550/kw-hr. Maintenance costs for the vehicle are estimated at 1/3 to 1/4 that of gasoline powered vehicles or about 0.30/mile. Unfortunately, the economics are not so favorable as far as first cost goes. The electric town



FIG~ 5 Tripolar cell construction of the batteries used to power MARS II car. All positive plates in a group of plates within the lead-cobalt

cell are structurally and electrically connected to one another in three appropriate places. The negative plates are likewise joined together.

car is at a decided disadvantage in this area as compared to American compacts and foreign subcompacts.

The physical and styling details of the car emphasize the needs of a town or short trip vehicle. Weighing approximately 2300 lb, the General Electric Delta has room for two adults plus two or three children or 24 cu ft storage. Its length is 10 ft 10 in., width is 4 ft 8 in., and height is 4 ft 11 in.

Mars II

The major features of the roomier Mars II vehicle are its tripolar, leadcobalt battery and its regenerative braking system which utilizes braking energy to recharge the battery. Four

30-v, 290-amp-hr batteries of this kind are used. They deliver approximately twice as much energy per pound as ordinary lead-acid batteries, and can be safely recharged at high currents to 8017c of capacity in 46 min.

All the positive plates in a group of plates within the lead-cobalt cell are connected to one another in three places structurally and electrically, see Fig. 5, and so too are the negative plates. The cell element is thus equipped with six current collecting bus bars, two at the top of the cell and four additional at the bottom. The multiple interplate electrical connections enhance the cell's ability to deliver and accept high current. The

bottom four bus bars, resting on the floor of the cell container and supporting the entire weight of the cell element through current and heat conducting legs, induce the cold and dormant acid on the bottom to rise and circulate through the cell whenever charging and discharging causes the plate temperature to rise. Due to the use of cobalt in the cells the production of very toxic stibine gas during the charging process is virtually eliminated,

An improvement of the tri-polar principle, not yet incorporated in production batteries used in the cars, connects the three poles of a group of plates within a cell to the three poles of a group of plates of opposite polar-

Mars II, a 4260-lb electric car, uses 77-hp motor to give 60 mph top speed.

ity in the adjacent cell. This increases the total current which a given battery can handle while decreasing the current through each individual current path. Current generated at the bottom portion of the plate travels a shorter distance, and the internal resistance of the cell is thereby reduced. Laboratory models of the improved battery indicate an increase of approximately 20% in current density over the existing battery.

The Mars II also uses a series wound dc motor, but this one can develop up to 77 hp at peak acceleration and gives the 4260-lb car a 60-mph top speed. A clutch connects the motor to a 4-speed-forward manual transmission which utilizes the inverse ratio that exists between torque (or current) and motor speed with the d-c motor. At low vehicle speeds in second gear, for example, the 2.25 gear ratio results in high motor speeds and low current consumption, while in fourth gear (ratio 1.03) motor speed is lower and current consumption and vehicle speed are greater.

Battery current is transmitted to the motor through a control panel which enables the operator of the vehicle to switch applied voltage and current at will through seven steps by applying foot pressure to the accelerator pedal. The driver of the car can thus operate the four 30-v batteries in parallel when starting and at low speeds (0-15 mph), in series-parallel at 60 v at intermediate speeds (15-30 mph), and in series at 120 v at higher speeds. This is advantageous since, at low and intermediate speeds, the specific energy of the batteries can be more efficiently utilized

parallel, thus providing for automatic equalizing of charge among the batteries and lessening the danger of overcharge of any of the batteries. In addition, charging at 30 v is safer than charging at 120 v to persons who may be in contact with the car.

The dual hydraulic braking system, with disc brakes on all four wheels, is supplemented by the previously mentioned regenerative braking system. This system is designed so that release of foot pressure from the accelerator pedal initiates regenerative braking. Not only does this provide the maximum amount of regeneration but also gives increased safety as braking starts even before the hydraulic brakes are activated. The system can produce a braking effort of up to 15 hp and could stop the vehicle in 500 ft from a speed of 30 mph in second gear.

In one specific configuration of the regenerative braking system the energy recovery is accomplished through an alternator, mechanically driven by the electric motor which drives the wheels. The alternator's output is then rectified and applied to the batteries. The storage batteries can also be recharged from an external source by simply exciting the motor with external power to mechanically drive the alternator.

Besides recuperating energy, the regenerative system helps promote battery life and efficiency since the intermittent recharging prevents horizontal layering or stratification of the electrolyte in the battery. Thus, more of the acid is effectively used in the discharge process and the constant circulation of the electrolyte prevents the water produced during

The car is also equipped with a built-in slow charger for overnight recharging of the power batteries and the 12-v accessory battery. It operates on a 208/240-v, single phase, 30-amp circuit and has an 8-hr recharging time for fully discharged batteries.

High rate charging receptacles are installed in the trunk area of the car and permit fast recharging of the power batteries at currents up to 1000 amps at 371/2 v from an external power source.

The practical range of the car is 70-120 miles per charge but the rapid rechargeability of the tri-polar, leadcobalt battery enhances the vehicle's utility. If stationary chargers having the capacity required for the Mars II ever become as commonplace as gas stations are now, the car would be feasible for the commuter who travels less than 230 miles a day. Before this happens, however, it is likely that 44 "plug-in" parking meters would be installed in metropolitan areas which could utilize the chargers built into electric cars. In this case, the maximum driving range for some commuters might be 150 or 160 miles per day.

Cost of operating this vehicle is figured to be roughly 20/mile, which includes the cost of battery depreciation. The battery life is assumed to be a minimum of five years or 50,000 miles and the replacement cost is \$600. The maintenance costs, as with any electrically powered vehicle, are expected to be very low. But, again, the first cost of this vehicle will greatly inhibit its acceptance by the public.

FOR FURTHER INFORMATION

The following publications were used in the development of this article:

680428 *The Ford Cornuta-An Electric Car for Use in City and Suburb*, by L. Martland and A. E. Lynes, Ford Motor Co., Ltd.; and L. R. Foote, Ford Motor Co.

680429 *Mars II Electric Car*, by Robert R. Aronson, Electric Fuel Propulsion Inc.

680430 *The GE Electric Vehicle*, by Bruck R. Laumeister, General Electric Co.

in parallel and series-parallel operation than if they were operated in series. Also, when the batteries are in parallel at low speeds they can handle the large surges of current often required by the motor. A further advantage of this method of control is that the batteries can be charged in

discharge from collecting at the plate surfaces and reducing the conductivity between them.

The alternator is a 37-v, 200-amp intermittent duty device which engages the motor through a belt driven, magnetic type electric clutch.

To order the publications listed above, circle the appropriate 6-digit numbers on the Reader Service Card preceding the yellow pages.
