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ELECTRICAL PROPULSION OF ROAD VEHICLES - SURVEY OF AVAILABLE LITERATURE.

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INTRODUCTION

Much has been said about air polution[1),3),12),15)] and its dangers to mankind. Especially internal combustion engine motor-cars contribute heavily towards the increase in lead[2)], carbon monoxide, and other pollutants in the atmosphere. The electrically powered car, on the other hand, not only causes no air pollution, but is also silent and requires little attention and maintenance. In addition, electric power distributors throughout the world should welcome the use of off peak electricity for charging storage batteries.

Although the number of electrically propelled vehicles, when compared with the very large number of petrol powered cars, are relatively few, it is illuminating to know that in the United Kingdom alone there were, according to Lee[12)], about 100 000 such vehicles in 1967.

The corresponding figure for the U.S.A. for the year 1965, as predicted by Erickson[11)], was 583 000 vehicles (which, incidentally, would consume about 1 648 GWh of electricity for the charging of batteries).

A further interesting fact disclosed by Lee is that about 80 per cent of the cars in the U.K. travel less than 20 miles a day and that this distance is decreasing. Such circumstances should in many instances render an electric car a practical proposition, even if only for town driving where frequent stopping is necessary, and especially where a family also owns the usual petrol driven car for longer journeys and heavier loads.

REQUIREMENTS

The real need for an electric car is at present probably felt in urban areas only, and thus its travelling range need not

/necessarily .....

necessarily be very great. Although a range of about 240 km without recharging batteries would be desirable, and has in fact been achieved in an American vehicle[4], a distance of about 65 km is more common with presently available cars.

The top speed for driving in town need not be more than 65 km/h*, and this is already featured in most of the existing vehicles. A minimum acceleration of about 2 m/s^2 should be aimed at.

Enough space to carry at least 2 persons and 65 kg of luggage is required. The outside dimensions of the car should be kept as small as possible to facilitate driving and parking in town. Such a car would supplement rather than replace the usual family car.

THE D.C. TRACTION MOTOR

According to Reid[5] an electric motor need have a kW rating of one-fourth to one-fifth that of a piston engine for the same service. A 5 - 11 kW rating would thus be adequate for a small electrical car, but motors of only 2,3 kW have also been used[7]. Forced air cooling of the motor is quite common. Such motors can have a mass/power ratio of under 5 lb/hp (3,04 kg/kW)[6].

Four different types of speed control have been described, of which the thyristor pulse control system is probably the most efficient. This may provide a 15 per cent energy saving over the more traditional resistance control using pressure sensitive carbon piles[6],[9].

Relatively little is known about the constant speed motor and electro-magnetic clutch system employed in some vehicles[8].

The fourth method used for speed control is by parallel-series switching of the batteries, motors, and field windings[18],[6].

/Coupling .....

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*This may be too slow when travelling over throughways where higher speed limits have been set.

Coupling the motor to the wheels is either direct or by means of chain drives, toothed belting[7),10)], or the more conventional gear arrays[9)].

The series connected motor has the most desirable torque characteristics for tractive use, but when regenerative braking[4),12)] is to be employed, a "slightly shunt or compound connected" motor is necessary[11)]. (The maximum recoverable energy from regenerative braking is less than 15 per cent[12)].)

ENERGY SOURCES

Energy for the motor is supplied by storage batteries, fuel cells, or even a small petrol engine driving alternators[13),12)]. The disadvantages of the latter system are quite obvious, but a small Stirling engine, which gives off low amounts of carbon monoxide and is relatively quiet, is less objectionable and has been used[13)].

All known commercially available electric cars still use lead-acid batteries which, as a result of their relatively high mass to power yield ratio, are not very suitable for this purpose. Extensive data on presently known types of storage batteries have been published[5),12),14)], but most of the promising newly developed batteries still seem to have mechanical or other drawbacks. A Japanese battery manufacturing company claims to have developed an efficient sodium-sulphur battery[16)], and this type was also used by the Ford Motor Co. in their experiments[12)]. Another promising battery seems to be the lithium-nickel halide type[4),12)], used in an American experimental car called Amitron. In South Africa suggestions regarding the use of a zinc-air battery[12),23)] have been put forward by the C.S.I.R.[17)], although it was at the same time decided not to do independent research in South Africa.

Fuel cells[24),5),12),11)], with their high energy conversion efficiency, may compete with batteries with regard to electrical performance, but they are still at least 20 times as expensive as lead-acid batteries. Their bulk also count against them at present, and the danger of explosive or toxic gases is always there.

/Steam .....

Steam[15] or solar energy[11] have also been quoted as possible energy sources. Other systems, for instance phase change systems or nuclear units, are not at all suitable at present[5].

NEED FOR AN IMPROVED STORAGE BATTERY

The main reason why the electric car has not thus far been accepted by the motoring public is probably because an acceptable substitute for the conventional lead-acid battery, or a considerably improved version of it, has not yet been forthcoming, in spite of determined and maintained efforts in many of the industrialized countries in the world to achieve this goal. The main trouble with the lead-acid battery is, of course, its relatively high mass/power ratio (lb/kW) which for an ordinary product of this type is about 31[12].

Table 1 provides data on various storage batteries which have been considered for electrically powered vehicles. It is interesting to compare the characteristics (where available) with the minimum requirements that would apply to an acceptable battery. Such minimum requirements have been suggested by Reid[5], and they are shown at the end of Table 1.

It is also noteworthy that the lead-acid battery appears to have the lowest energy density (Wh/lb) of all the batteries considered for traction purposes.

Thus, if such a battery is used to power a 3 000-lb delivery van, and the battery weighed (say) 850 lb, the operating range would only be 40 miles. With a zinc-air battery of similar mass the operating range would be 200 miles[23].

/TABLE 1 .....

TABLE 1

TYPES OF STORAGE BATTERIES AND MISCELLANEOUS DATA CONCERNING THEM

Type of battery	Temp. of operation, °C	Mass/power ratio, lb/kW	Energy density*		Recharging cycles after deep discharging	Estimated cost of	
			Wh/lb	Wh/in^3		Battery, R/kWh	Energy, R/kWh
Lead-acid SLI**	Ambient	31	15-16	0,8-1,1	200 ***	17	0,14
Lead-acid Industrial			10-12		2 000	55	0,06
Sodium-sulphur	250 - 300	10	68-136	-	1 000 (?)	-	-
Zinc-air	-	-	50-60	-	-	-	-
Nickel-iron	-	-	10-13	0,5-0,6	2 500	111	0,07
Nickel-cadmium	-	-	14,5-16,5	1-1,1	2 000	233	0,15
Silver-cadmium®	-	-	27-31	2,2-2,6	-	-	-
Lithium-chlorine	500-650	-	-	-	-	-	-
Lithium-nickel halide	-	-	100	-	(Many (thousands	-	-
Minimum requirements (according to Reid[5]))	-	-	75	2,2	500	9,4	-

*The faster the rate of discharge, the lower the energy density becomes.

**Battery for starting, lighting and ignition as used in an ordinary petrol powered car.

***The wattage efficiency for charging and discharging the lead-acid battery is about 75 per cent.

®Silver-zinc batteries are also well known. They are, however, expensive and, although they have a high output per unit mass, they have a short life and are, therefore, unsuitable for vehicle propulsion[12]).

/ECONOMIC .....

ECONOMIC CONSIDERATIONS

Judging by Reid's observations[5], battery operated road vehicles were not yet attractive economically in 1965. His main arguments were as follows: If relatively light lead-acid batteries capable of providing a travelling range of 150 miles at 40 miles/h were used on, for instance, a converted Volkswagen car, the batteries alone would weigh 700 lb more than the unconverted car (which weighs 1575 lb). Heavy duty industrial batteries - which should actually be used as this would ultimately be much more economical - would weigh twice as much as the car and would cost 1,5 times the cost of the car. The cost of delivered energy in such a case would, however, still be 50 per cent more than if gasoline were the fuel*. Capital and running costs with all other known types of storage batteries would be considerably higher. Reid considers that a hydrogen-oxygen fuel cell using gas generated by electrolysis would appear to be the most promising alternative to storage batteries from an economic point of view.

Reid quite rightly points out that if electricity were used widely for automobiles, provision would have to be made in the running costs for taxation which is now included in the price of petrol.

The cost of a battery electric vehicle is, of course, very much dependent on the maximum radius of operation between battery recharges and also on maximum speed, which factors mainly determine the size and weight of the batteries. (This explains why the electric car may, initially at least, have to be limited to town driving.) Ericson[11], for instance, has calculated that an increase of the speed of a vehicle from 25 to 50 m/h would increase the theoretical power requirements about 3,8 fold.

In another comparison of costs when considering an electric vehicle doing not more than 100 miles per week

(presumably .....

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*The price of petrol today is probably appreciably higher in most countries than the price considered by Reid in his calculations.

(presumably about 20 miles per day), the total running costs per mile were only about one third of those for a petrol driven vehicle, and the total operating costs per mile about three-quarters[10]. More detailed cost items provided are as follows: Vehicle £300; battery £150; running costs with electric current at 0,8 d/kWh, and consuming 12 units/30 miles: 0,32d/mile. The total operating cost, with standing charges and 20 per cent depreciation included: 8,54d/mile. (For a corresponding petrol vehicle these figures are: Vehicle R475; running costs, with petrol at 5/-/gallon, 30 miles/gallon: 2,08d/mile; total operating cost: 11,73d/mile.)

In evaluating the operating cost of a car driven 5 000 miles a year, Ericson concluded[11] that for the electrically driven vehicle the total operating costs (4,5 U.S. c/mile) would be about five-eighths of those for its gasoline powered counterpart (7,2c/mile). The lower rate of depreciation of the more durable electrical components would materially increase the advantage pertaining to the electric vehicle.

According to data supplied by Hender[6], it is much more economical to use battery driven vehicles for daily milk deliveries in towns than petrol driven vehicles. (This is probably mainly due to the high percentage of stopping time.) The author also describes numerous improvements to batteries, electric motors, methods of electric current control, etc., which have considerably reduced costs.

The estimated price (including batteries but without charger) in 1966 of the Scamp - an experimental electric car - was £330[10], which can be considered reasonable. However, the price of £550 (in 1969) for the Enfield 465 two-seater with a range of only 36 miles and a top speed of 40 miles/h is considered as "rather expensive"[3].

The price of the Italian electric car, Urbanina, which has an operating radius of 180 km and a top speed of 60 km/h, is reported to be in the range of £350 to £500 (presumably excluding the 4 batteries which cost £50)[20]. Its running costs are stated to be approximately about 1 penny per mile as compared with about 4 pennies per mile for a Fiat 500.

/(Additional .....

(Additional data of economic importance appear in Table 1.)

PROTOTYPES AND COMMERCIAL VEHICLES

Relatively few electric cars have become available commercially[22), 7),19),20),31)] and as far as is known all commercial units still use lead-acid batteries.

In England, experimental models much as the Flamenco[6)], Scamp[10)], and two converted Minis[10)] have been built. Commercially available vehicles are the Carter Coaster[8)] and the Winn City Car[12)].

Quite a few electric cars are available in Italy. These are the Urbanina[20)], the Rowan[7)], and two converted Fiats[7)]. No new ideas are featured in any of these.

The Americans have probably built most of the experimental models. Ford has built the Comuta[9)], and General Motors a hybrid Stirling-Electric car[13)], and also the Electrovair II and the Electrovan[12)]. American Motors developed the promising Amitron[4)], with a dual battery system, viz., a nickel-cadmium battery for the high peak power necessary for acceleration and a lithium-nickel fluoride battery for cruising.* The U.S. Bureau of Mines also extensively tested an experimental battery-powered vehicle[18)].

In France, a small vehicle - the "Electrocart" - has been made available for carrying parcels or people.

In South Africa, a "Buggy" has been placed on the market[19)] for use in mines, and a nursery in Pretoria uses two imported electric vehicles for conveying people and materials[22)]. Some experiments have been conducted at the Fuel Research Institute with a car converted to battery-powered traction[26)].

/CONCLUSION .....

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*Other data pertaining to the car are: Max. speed 50 m/h; range 150 miles; time for recharging batteries 4 hours, but a 30 minute charge using the ordinary domestic current will be enough for driving 20 miles.

CONCLUSION

It has been shown that an electric vehicle could be economically attractive[6),10),11),18),25)], and other advantages have been mentioned. The success of such a car, however, will probably be determined by the public's willingness to accept a slower and less powerful car having a reduced travelling range, as well as by the manufacturers' ability to develop improved storage batteries and acceptable car models. The rising price of petroleum products and the fight against atmospheric pollution may also hasten its general acceptance.

(SIGNED) J.H. LA GRANGE

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PRETORIA.
26th July, 1971.
/TW

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