ELECTRIC CARS

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INTRODUCTION:

Recently the growing awareness and concern over the problems of exhaust pollution and automotive noise has caused a renewed interest in alternative propulsion systems. A further factor of increasing importance is the need to conserve primary energy sources, particularly oil. Since it appears likely that vehicles will continue to require to carry their own fuel supply the two main requirements in selecting a propulsion system are:-

i) A method of energy storage.

ii) A method of converting the stored energy to mechanical power.

We will, first of all, discuss these two aspects before looking in more detail at a particular combination, electro-chemical energy storage and electric propulsion.

Energy Storage:

For vehicles which carry their own source of fuel we are interested in the size and weight of the fuel required for a given journey. This will depend on a number of factors, including how much energy is released by unit mass of fuel, and how efficiently this energy can be converted to mechanical power. Also, whether it is necessary to carry the oxidant in addition to the fuel - as is the case for the lead acid battery, or can one use oxygen from the air as is done in the petrol engine? An indication of the relative suitability of various fuels on an energy to weight basis is given in Table I.

From this table we see just how good petrol is compared with its alternatives. Whilst nuclear fuels have a very high energy/weight ratio other considerations such as cost, minimum size and safety rule them out for small vehicle production. Flywheels, and thermal storage all have merit for special applications but, in practice, we are left with the chemical fuels as the only really feasible form of energy for this application.

Conversion Systems:

Having selected chemical stored energy as our energy source we should consider the various processes by which it can be transformed to mechanical power.

The fuel can be burnt in the engine as in the conventional internal combustion engines the diesel and the petrol engine, or in variants of these such as the Wankel engine. The discontinuous combustion process in these engines results in noise and exhaust products due to incomplete combustion. In the gas turbine, also an internal combustion engine, the combustion process is continuous.

Alternatively, fuel can be burnt outside the engine in the external combustion engine, or heat engine. The combustion process can be controlled more effectively than in the internal combustion engine, and also does not require additives to the fuel. As a result engines are quieter and have improved exhaust characteristics. Heat engines are limited in efficiency by the Carnot limit, but more important in practice is the requirement for two heat exchangers resulting in high cost and size.

Both the preceding engine types are considered elsewhere in this conference so we will discuss the third type of engine, electrochemical converters in more detail.

Chemical fuels can be converted directly to electricity in the fuel cell, alternatively electrical energy may be stored in the form of chemical energy in a storage cell and reconverted to electrical energy as required.

Both internal and external combustion engines can be combined with storage batteries in the form of hybrid converters.

Electrochemical Energy Storage 1,2,3,4:

The following storage batteries are commercially available:

(i) The Lead Acid battery: Well developed, reliable, inexpensive; specific energy 12 whr/lb. Specific power 10-50 w/lb. Good recycling life.

(ii) Nickel Iron battery: Well developed, reliable, robust. Similar in specific energy to lead acid battery but more expensive, poor low temperature performance, no advantages over the lead acid battery for this application.

(iii) Nickel Cadmium battery: Somewhat higher specific energy than the lead acid battery but several times more expensive; also requires cadmium which is relatively scarce material. Offers very high specific power 180 w/lb., in addition to this high discharge current these batteries can be recharged at a high current and hence have a rapid recharge time. Good recycling life. Can be useful, used in association with lead acid batteries to improve overall specific power.

(iv) Silver Zinc battery: Very high specific energy 40-55 whr/lb., and specific power 100 w/lb., but suffers from short recycling life, 100-200 cycles, and is prohibitively expensive for present application.

Thus, for the immediate figure we are restricted to the lead acid battery, possibly backed by nickel cadmium batteries for providing power peaks.

In the future, batteries of higher specific energy will be developed by making use of either/or air electrodes (the semi-fuel cells) and lightweight metals such as sodium or lithium.

These developments hold out the promise of realising the specific energy of $>$ 100 whr/lb. and specific power of $>$100 w/lb necessary to give an overall performance comparable to that of the i.c. engine.

(v) Zinc Air battery: Currently 50 whr/lb. with possibility of improvement to 70 or 80 whr/lb. The recycling life is not yet satisfactory. Other metal air combinations offer the possibility of greater specific energy, but are at an earlier stage of development.

(vi) Sodium Sulphur: Offers both high specific energy (150 whr/lb) and specific power 150 w/lb. Requires to be operated at a temperature of 300°C and will have start up problems. Corrosion will require careful selection of constructional materials. The basic reactants are cheap and there is the possibility of a good recycling life. There may be a safety hazard in the event of a collision.

(viii) Zinc Chlorine battery: Offers possibility of 50-75 whr/lb and 40-60 w/lb. at ambient temperature and cheap materials. There maybe a safety hazard.

All these above energy storage devices are subject to the two basic limitations of storage batteries, they require to be charged electrically which is inconvenient and time consuming and the battery size determines both the energy stored and the power output.

The remaining possibility is the fuel cell which does not suffer from either of the above limitations, but does require heat exchangers, pumps and other ancillaries.

(ix) The Hydrox Fuel Cell: The most developed, reliable and best understood of the fuel cells. Even this cell has a rather poor specific power 10-20 w/lb and requires an expensive and bulky, fuel, hydrogen. The cell must either be operated hot (200°C) or make use of expensive catalysts.

(x) Hydrogen Fuel Cells: The hydrocarbon may be reformed to give hydrogen which is burnt in a Hydrox Fuel Cell or burnt directly in a high temperature cell. The former is both bulky and expensive and the latter is in an early development stage. Neither offers the hope of a cheap system. A further possibility is the use of methanol dissolved in the electrolyte. This requires the discovery of a cheap catalyst before it can be considered as a realistic possibility.

Electric Motors and Control: In order to convert the electrical energy into mechanical shaft power, we require an electric motor, together with a transmission system and means of control. Overall efficiency of this conversion system is clearly very important and weight may have to be increased to permit greater efficiency, since it is likely that the motors and control will be lighter than the battery system.

Both conventional (13) : (14) d.c. or a.c. motors may be used. The specific power of the motor will be determined by its speed which in turn is limited by the form of construction. A.c. motors may be operated at higher speeds than d.c. motors. It is unlikely that printed circuit motors will be adopted because of the speed restriction due to the large diameter rotor. The homopolar motor is of interest but is a high current low voltage device and the control of these high currents may be both expensive and bulky.

Hybrids: It may be possible to combine the advantages of two separate systems to produce an overall system, a hybrid, having performance superior to either individual system. For example, the high specific energy of the fuel cell together with the high specific power of the storage battery is a possible combination. The use of internal or external combustion engines operating at constant power output and maximum efficiency in association with storage batteries have also been considered. An example is the General Motors Stirlec, a 8 h.p. engine acting as the battery charger for a bank of lead batteries which, in turn, drive a 20 h.p. induction motor. A further advantage is that the vehicle can run entirely on batteries for town use. Again, if the batteries become discharged they may be recharged in situ from the engine. The efficiency of the hybrid is high, since the engine always operates at full load; on the other hand, capital cost is likely to be higher than for single systems, particularly for small vehicles.

Electric Cars: Present Position and Prospects: Electric propulsion is widely used for powering milk floats, delivery vans, fork-lift trucks and other small vehicles such as golf carts. However, in spite of the long history of electric car development, the large development efforts of the past decade, and the extensive use of electric propulsion in special applications the general situation is disappointing. A number of small cars (17,18) using lead acid batteries and having limited range and performance have been constructed, but to date no efforts have been made to manufacture such vehicles on a large scale.

A number of these designs are conversions of petrol engined cars to electric propulsion. In making such a conversion one tends to compound the limitations of both types of power supply. For example, if in a design we accept a low top speed we no longer require the same road holding and suspension characteristics; this both cheapens the design and provides more geometrical flexibility. One feature which might profitably be introduced in a small 'second car' is the concept of plug in units, e.g. golf carts, shopping trolleys in which a child could be permanently seated, etc.

A characteristic which should be exploited is the potentially long life of the propulsion unit (less the battery) and its relative freedom from maintenance. Coupled with a lightweight plastic light alloy structure a life of 20 years should be possible.

Several higher performance,(19,20,21) larger vehicles have also been reported. These prototypes employed advanced design batteries and fuel cells but significant advances in battery design will be necessary before the electric car is commercially competitive with the I.C. engined vehicle.

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