

driving it through planetary gears. This last arrangement, though the most felicitous on first observation, may result in an unavoidably harsh ride and unpleasant jounce from almost doubling the present unsprung weight by adding 1 percent of  $W$  (each motor) to each wheel-tire assembly; it would also pose unusual problems of heat dissipation into the tires from the motor.

#### IV. CHOICES OF BATTERIES AND RANGES

As seen in the last section,  $Y$ , the weight portion allocable for electrical energy storage and delivery, is about half of the curb weight—specifically  $Y=0.49$ . Two types of electrochemical energy-storage delivery systems are considered here as taking up this half of the curb weight: conventional batteries, or regenerative fuel cells with ambient air as the oxidizer source (hereafter called air-batteries for brevity).

TABLE 3.—*Properties of batteries in the near future*

##### (a) INDUSTRIAL BATTERIES

| Type           | Symbol  | Energy density $d$ , watt-hours per pound | Discharge time, hours | Method for calculating $d$                                                                                                                                                                                    |
|----------------|---------|-------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lead-acid      | Pb-acid | 10                                        | 0.5                   | Manufacturers' literature on heavy-duty diesel batteries. Reference 7: R. C. Shair, "Sealed Secondary Cells For Space Power Systems" <i>Journal of Spacecraft</i> , vol. 3, No. 1, January 1966. Reference 7. |
| Nickel-cadmium | Ni-Cd   | 20                                        | 1                     |                                                                                                                                                                                                               |
| Silver-zinc    | Ag-Zn   | 30                                        | 1.5                   |                                                                                                                                                                                                               |

##### (b) HYPOTHETICAL AIR-BATTERIES

|              |            |    |   |                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------|------------|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Zinc-air     | Zn-air     | 50 | 3 | Reference 8: Hines, E., Porter, J. T. and R. J. Newman, "Zinc-Air Battery R. & D. Shows Promise" <i>Electrical World</i> , Aug. 23, 1965, p. 105. Scale-up of present cell-stack weights, with $H_2$ tank, plumbing and pumps added. Reference 9: M. G. Klein, "Electrolytically Regenerative $H_2$ - $O_2$ Fuel Cell Battery" proceedings, 20th Annual Power Sources Conference, Box 891, Red Bank, N.J., 07701, May 1966. |
| Hydrogen-air | $H_2$ -air | 60 | 4 |                                                                                                                                                                                                                                                                                                                                                                                                                             |

Table 3 lists the salient characteristics of commercial and aerospace batteries, on the assumption that an intensive upgrading effort would be successful in adapting these batteries for powering automobiles in the near future. Table 3 also presents (for illustrative purposes only)