(potentials > −500 mV *vs.* Hg/HgO), dissolution of formed oxide occurs, producing an Fe(III) ion. All three dissolution processes increase with both temperature and hydroxide concentration. In 7-molal NaOH, significant reductive dissolution was observed at temperatures above approximately 40 °C, and anodic dissolution at temperatures above 80 - 100 °C.

(iii) For Ni and Fe, the total reversible charge and the rate of reversible processes generally increase with increasing temperature.

(iv) At full charge, the extent of coulombic inefficiency due to oxygen evolution on the Ni electrode and hydrogen evolution on Fe was observed to increase roughly with e^T/T, consistent with Tafel's law. Hydrogen evolution on Fe at elevated temperatures detracts significantly from the performance of this electrode, and occurs at a significant rate at potentials more positive than the $Fe/Fe(OH)_2$ couple.

In addition to experimental studies, calculations have been completed from which a complete set of potential–concentration diagrams (analogous to potential–pH diagrams) can be constructed covering the temperature range −20 to +120 °C.

Within the schedule duration of this project, SRI intends to complete experimental studies of Zn, to construct potential–concentration diagrams for metal/NaOH solutions, to analyze and collate all experimental data, and to incorporate these in the final report. In further experimental studies of Zn, we intend to concentrate primarily on temperature limitations associated with dissolution and passivation, utilizing a rotating, vitreous carbon ring, Zn disk electrode.

ENERGY STORAGE SYSTEMS FOR AUTOMOBILE PROPULSION

University of California, Lawrence Livermore Laboratory, Livermore, CA 94550 (U.S.A.)

This project continues the ongoing multi-DOE laboratory analytical study to evaluate the updating of energy storage devices and their suitability in energy storage propulsion systems for automobiles. The study this year includes: (a) updating the previous projections of energy storage device characteristics and the technical analysis of their utilization in propulsion systems; (b) the preparation of these data for addition to a national data base; (c) the analysis of the technical and economic tradeoffs for new systems; (d) an energy impact analysis of these systems; (e) an examination of the financial and infrastructure requirements of selected energy storage vehicles (ESV's); (f) an investigation of ESV specialty markets. The ultimate goal of the project is to determine which energy storage devices and power systems are most likely to provide credible alternatives to current and future internal combustion engine (ICE) propulsion systems between now and the year 2000.

Using the results of the study reported at the end of 1977, the 1978 work concentrated on examining the following:

(i) The effect on all-battery electric systems of optimizing batteries for the specific peak power and specific energy relationship.

(ii) The effect on the relative results of using highly optimistic (10%) confidence level component characteristics.

(iii) The national energy impact of the future introduction of energy storage automobiles.

(iv) The effect on prior results and conclusions of R & D achievements in the past year.

As a result of this multiyear effort, we draw the following conclusions:

(a) Some energy storage systems have the potential at various times between now and the year 2000 to provide vehicles with both range and acceleration performance essentially equivalent to today's automobiles except for costs and, in some cases, safety considerations. These systems include: dual-fueled hybrids; power-leveling heat-engine hybrids; refuelable metal–air electrics; roadway power systems; liquid hydrogen.

(b) Most energy storage vehicles will weigh and cost more than ICE vehicles of equal performance. This cost differential will decrease in later time periods.

(c) Many energy storage devices are projected to be suitable for specific-mission applications (intermediate-, limited-, and minimum-performance levels). Some specific-mission automobiles, particularly those of limited and minimum performance, can have costs comparable with present day ICE automobiles.

(d) All advance energy storage vehicles are high-risk developments with difficult technical and economic problems.

(e) While specific-mission energy storage automobiles should find limited use in the future automobile market, the introduction of general-purpose energy storage vehicles will be required before these vehicles will make a significant impact in reducing the kilometres traveled by gasoline vehicles and before a significant reduction in petroleum consumption by the highway vehicle system can occur.

These results have been published in a two volume report (UCRL-52553) and presented for general discussion in an open workshop during June, 1979.

The current study phase is approaching the point where the various contractor-chaired panels will be submitting reports to LLL on their assigned task work. This will allow, within the remainder of 1979, the completion of the automotive end use analysis of the data at the Lawrence Livermore Laboratory and the completion of the final report. This year a summary report will be prepared covering the three (plus) years of this continuing study.

Recent publications

1 M. W. Schwartz and E. Lorbeer, Preliminary design analysis of the quasi-electric drive vehicle, *UCRL-52613, 1978.*
2 J. F. Cooper, Mechanically rechargeable metal–air batteries for automotive propulsion, *UCRL-81178, 1978.*
3 E. Behrin, *et al.*, Energy storage systems for automobile propulsion, *UCRL-52553, Vols. I & II, 1978.*

A HAZARD ASSESSMENT OF ZINC–CHLORINE ELECTRIC VEHICLE BATTERIES

Factory Mutual Research Corporation, Norwood, MA 02062 (U.S.A.)

This project is designed to evaluate the potential hazards of zinc–chlorine hydrate batteries for electric vehicles. The consequences of accidental release of chlorine following a vehicle collision and other potential mishaps will be determined from a combination of theoretical modeling, laboratory experiments, and field tests. The laboratory and field tests will determine the rate of chlorine vapor evolution and dispersal following a spill of chlorine hydrate, which is the form of chlorine storage in the charged battery. Theoretical projections of casualty levels will be compared with statistics of current casualties associated with gasoline-fueled engines in conventional vehicles.

During the first half of 1979, seven laboratory spill tests involving 240 - 600 g of chlorine hydrate were conducted. The chlorine content of the hydrate varied from 3 - 34%, simulating the battery charge range from slightly charged to fully charged. The spilled hydrate resembled a slush with a consistency dependent on the simulated state of battery charge. Approximately one-half of the chlorine content in the hydrate vaporized in the first 15 min following the spill in most of the tests.

Another accident scenario involving chlorine vapor release in a longitudinally ventilated road tunnel was theoretically modeled during this reporting period. For a vapor release rate of 30 l/min (the nominal chlorine gas flow rate during charge), the calculated tunnel cross-section averaged chlorine concentrations ranged from 2 to 5 ppm for typical tunnel sizes and ventilation rates. These calculated values are below the threshold for any serious injury during transient exposure. Other tunnel accident configurations are to be modeled during the third quarter of 1979.

The highlight of this project during the third quarter of 1979 will be the field spill tests with a simulated full-scale 50 kW h battery store of chlorine