

of 0.26 g/ml of store volume will be pursued, as will programs to ensure the formation of  $\text{Cl}_2 \cdot 6\text{H}_2\text{O}$ , rather than the less dense  $\text{Cl}_2 \cdot 8\text{H}_2\text{O}$ .

### Recent publications

- 1 P. Carr, Zinc-chlorine hydrate battery, *Second Annu. Battery and Electrochem. Technol. Conf.*, Arlington, VA, June, 1978.
- 2 W. L. Pickwick, Test facility and test guidelines for the 50 kW h zinc-chloride battery, *Topical Report, Contract No. EY-76-C-02-2966, March, 1979.*
- 3 Chen H. Chi, Vehicle battery design — modeling of zinc-chlorine batteries for electric vehicles, *Topical Report, Contract No. EY-76-C-02-2966, June, 1979.*
- 4 H. K. Bjorkman, Chlorine hydrate store development, *Topical Report, Contract No. EY-76-C-02-2966* (currently being written).

### DEVELOPMENT OF ZINC-BROMINE BATTERIES FOR UTILITY ENERGY STORAGE

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The goals of this program are to perform a cost and design study for an 80 kW h zinc-bromine stand-alone battery module and to build and test three 8 kW h submodules. These are intermediate milestones for a three year program whose overall goals are the construction and testing of an 80 kW h zinc-bromine BEST prototype module by August of 1981.

The design layout of the 80 kW h module is complete; there are to be 10 identical 8 kW h submodules of either monopolar or bipolar design (the decision between the two is to be made just prior to module construction) contained on a 4 ft. × 8 ft. skid. Two electrolyte circulation systems, one each for the negative and positive electrolytes, are connected to the cells in a series-parallel array. These, constructed of polypropylene pipe for chemical resistance, provide electrolyte and bromine flow to the cells, since most of the electrolyte and bromine are stored in external tanks.

Three 8 kW h submodules are under construction for design evaluation and performance testing. Two of them are monopolar submodules, comprising nonporous titanium negative electrode substrates, porous, flow-through titanium positive electrode substrates, and microporous separators in a filter press stack. Injection-molded polypropylene frames contain the electrodes and provide paths for electrolyte circulation in the stack. The third is of a bipolar design, in which carbon negative electrodes are pressed back to back with porous titanium positive electrodes in bipolar electrode pairs, also in a filter press stack.

During the remaining two months of the contract the three 8 kW h sub-modules will be performance tested for cyclability and efficiency, and the costing for large volume production of 80 kW h modules will be performed in accordance with the DOE/EPRI Standardized Costing Methodology.

The major technical problems are concerned with the voltage losses in the submodules. For the monopolar design, the voltage efficiency is limited to 50 - 60% owing to the ohmic losses in the current collection tabs and within the electrodes themselves (the terminal effect). To reduce these losses we are considering an electrode size scaledown from 1 ft.  $\times$  1 ft. to  $\frac{1}{2}$  ft.  $\times$   $\frac{1}{2}$  ft. This will not only reduce the magnitude of the current in the tabs but also the distance it must travel within the electrodes. There will be a per kW h cost increase because of this change, and also a slight penalty of energy density. The improvement in performance will, in any case, outweigh these disadvantages.

In the bipolar design there is an excessive voltage drop where the electronic current flows from a negative electrode to the positive electrode with which it is back-to-back. Presently the contact between the two is only *via* pressure applied through the entire stack by clamping bolts. Various techniques are under investigation permanently to join the bipolar electrode pairs, to insure a low resistance current path.