

IMPROVEMENTS IN SAFETY TESTING OF LITHIUM CELLS

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ABSTRACT

A systematic approach has been developed for evaluating the basic safety parameters of high power lithium soluble-cathode cells. This approach consists of performing a series of tests on each cell model during the design, prototype and production phases. Abusive testing is performed in a facility where maximum protection is given to test personnel.

INTRODUCTION

Lithium cells with spirally-wound anodes are used extensively in applications where high power is required. These cells have the capability of delivering high current densities as a function of the anode surface area. In designing and fabricating high-power cells, considerable attention must be given to the evaluation of safety.

While all of the cells of this type manufactured at our facility are protected by external fuzes against short-circuiting, consideration must also be given to the behavior of the cells under a variety of abusive conditions.

A system has been established for evaluating new cell models during the design, prototype and production phases. Cells are subjected to some abusive conditions which may possibly be encountered during usage. In addition, cells are also evaluated under conditions of severe abuse which may cause rupturing and release of the cell contents. In some cases, the sudden release of energy may be of considerable force.

All of the abusive tests on our cells are done in a special facility that was designed to give maximum protection to the test personnel and equipment.

DISCUSSION

I. FACILITY DESCRIPTION

The abusive test facility consists of several test bays which have reinforced concrete walls, heavy steel entry doors, blow-out walls and high volume exhaust systems.

Feed-through ports are provided for cables and sensor wires so that measuring equipment can be located outside of the test bay. Alarm beepers are also activated to signal that a test is in progress and to warn personnel about entering the test bay.

In addition, each bay has a thick laminated glass window which permits direct viewing and video recording as the test is being conducted.

Severe abusive tests, where the full energy of the cell or multi-cell battery pack may be released, are readily and safely contained in these test bays.

Some of the types of severe abuse tests which are conducted are:

- puncture
- crush
- incineration or rapid heating with electrical heat tape
- charging at high rates
- forced overdischarge at high rates

II. SYSTEMATIC APPROACH TO SAFETY TESTING

A. DESIGN PHASE

The evaluation of safety parameters and margins starts during the design phase of new models.

After cells are fabricated by the Research and Development scientists, they are subjected to short-circuit testing using shunts that apply a resistive load of less than .01 ohms. Current and temperature are monitored during the test to characterize behavior. In addition, cells are discharged at high and moderate rates, while current, voltage and temperature are monitored. Initial force discharge tests are also performed to (prove/evaluate) the basic cell design.

The results of these tests are used to evaluate the safety of the basic design and to determine if the cells are essentially qualified to build and handle. At this stage, the results of the tests may be used to change or improve the design (TABLE I). Also, preliminary sketches of cell components are made and transferred to engineering.

B. ENGINEERING PROTOTYPE PHASE

After the design of the model has been established, Engineering prototypes are fabricated. These units are built with production equipment and tolerances and the safety testing at this phase consists of:

- maximum current discharge at maximum operating temperature
- short-circuiting with and without fuzes
- DOT-E-7052 requirements of altitude simulation, thermal stability, vibration testing
- force-discharge at moderate rates
- drop testing (five feet onto a metal plate)
- full drawing packages are prepared at this time

The results of this series of tests determine if the unit is qualified to ship and to be used safely under the conditions described on the cell label.

Standard discharge tests at several rates are also done to determine the normal cell performance, but a primary focus of all testing is to establish the safety of the design.

During this phase, severe abusive tests such as crushing, incineration or high rate heating, puncture and charging may be done to further characterize the safety tolerance of the design (TABLE II).

C. PRODUCTION PHASE

The safety parameters and margins were studied during the design and engineering phases for the particular models which were made by well defined sets of processes and specifications.

In order for the safety test results to be valid, it must be determined that cells are made consistently and that processes do not vary inordinately. In our system, statistical quality control techniques are used. These techniques incorporate trend charts and other analyses to assure that processes are not subtly changing, thereby resulting in cells that deviate from the design which had been thoroughly characterized during the previous phases.

In some cases, processes may be deliberately changed in order to effect cost improvements, efficiencies etc. When changes are made or contemplated it becomes a responsibility of the Engineering and Reliability groups to qualify the change. This often requires that safety tests be repeated and a new safety assessment be made before the change is incorporated or cells are put into use.

In addition to the standard discharge tests, cells are stored for various periods of time and under varying environmental conditions. Periodically the stored cells are tested under conditions of normal and abusive tests to evaluate behavior and sensitivity over an extended period of time (TABLE III).

SUMMARY

Lithium soluble cathode cells go through extensive safety assessment using a systematic approach. This approach has resulted in cells and designs which are well characterized in terms of safety and performance.

Abusive tests are performed in a special facility where a maximum amount of protection is given to the test personnel. This facility permits testing to be done on cells and battery packs where they are deliberately abused beyond their limits thereby releasing their full energy.

By analyzing the results of the normal and severe abusive tests safety margins can be established and design improvements can be made.

The test results also form a base line of data so that comparisons can be made periodically between the production cells and their prototypes.

In addition, quality and process control techniques are used in the production phase to assure that the basic design and processing is being maintained. As a result, the safety and performance testing results remain valid throughout the production phase.

Where changes are introduced in the processing of cells and components, they are qualified by repeating safety tests and updating the baseline.

Table I. DESIGN PHASE FOR NEW MODELS

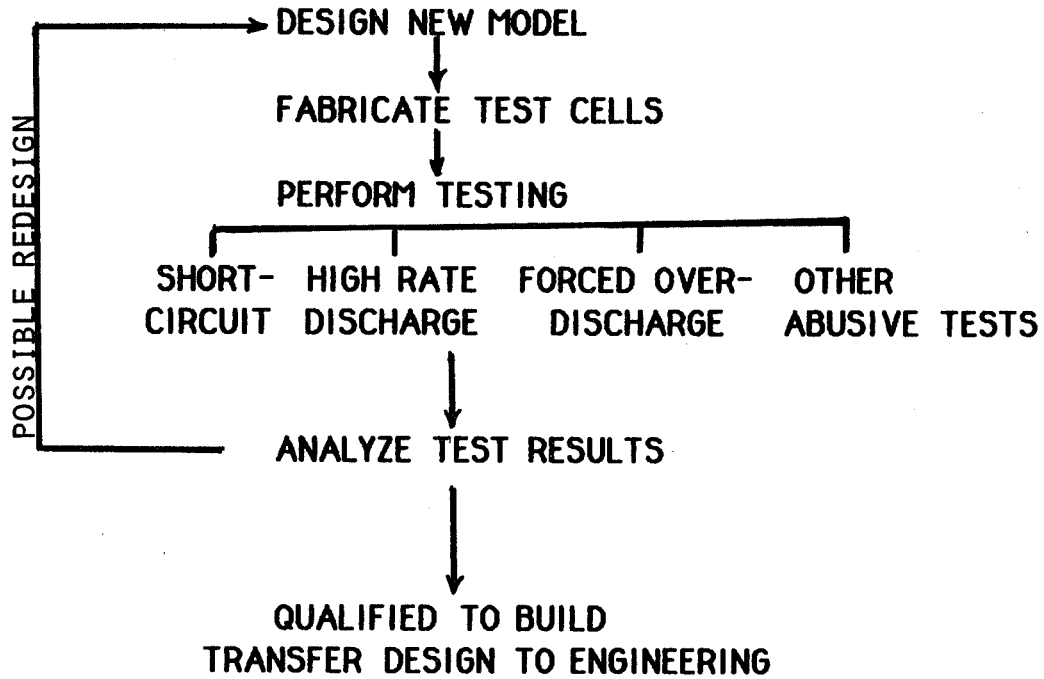


Table II. ENGINEERING PHASE FOR NEW MODELS

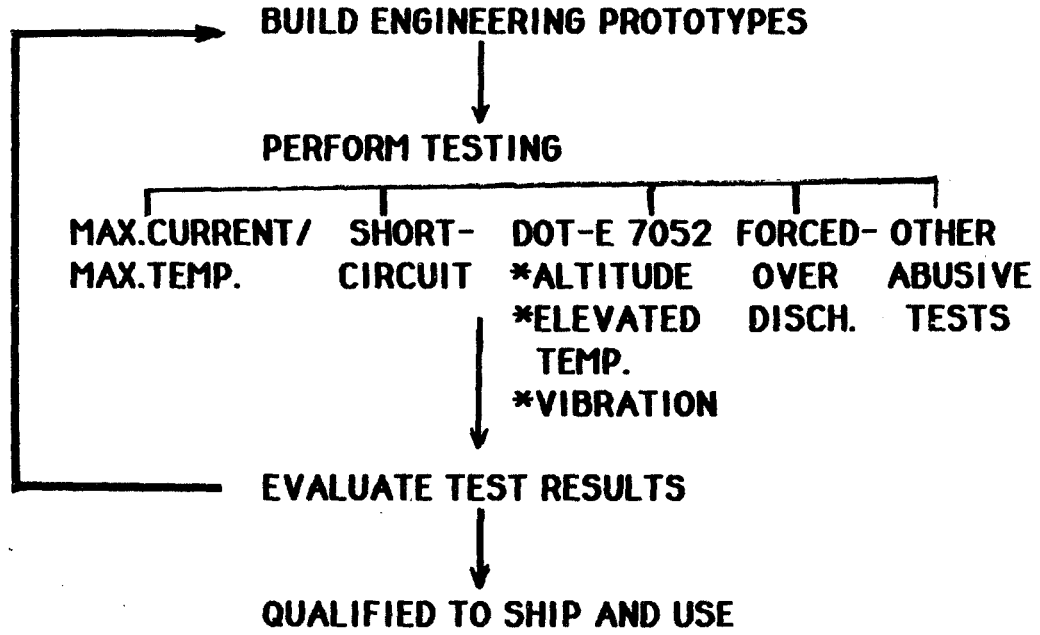


Table III. PRODUCTION PHASE OF NEW MODEL

