

RESERVE Li/SOCl₂ BATTERY SAFETY TESTING*

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INTRODUCTION

Recent development and test effort at Sandia National Laboratories and Honeywell Power Sources Center has been directed at high rate Lithium-Thionyl Chloride batteries which address applications previously specifying thermal batteries. These applications typically demand reserve batteries having rapid rise times, high power capability, with operational life profiles extending from minutes up to 1 or 2 hours. This development work has resulted in the generation of battery parametric design information and concepts in a reserve mode for high rate applications.

Data obtained to date indicate that for some applications, the Li/SOCl₂ reserve systems being developed will have advantages over thermal batteries. These advantages occur primarily in terms of rate capability per unit volume, lower battery operating temperatures, longer life, and in some cases, improved rise time.

BATTERY DESIGN

A cross section of one such reserve 16-volt battery is presented in Figure 1. The battery contains five (5) torroidal shaped cells packaged in nested or stacked individual plastic cups.

Electrolyte is held in reserve within a stainless steel welded bellows assembly located on one end of the battery. Surrounding the outside of this bellows assembly is a pressure plenum containing Freon gas which provides the pressure required to collapse the bellows and thereby transfer electrolyte to the cells upon battery activation. This highly reliable approach has been used on key development programs at Honeywell where rapid omnipositional activation of a reserve battery is required. In particular, it has found application in underwater Navy mines/buoy programs.

Battery activation is accomplished when a piston actuator assembly protruding through the terminal plate of the battery assembly is electrically initiated. The actuator output shaft moves a sealed nickel diaphragm forcing an internal cutter within the battery through the seal holding electrolyte within the bellows assembly. Cutting of this seal activates the battery by allowing the Freon pressurized bellows system to function as described above.

* The battery development work presented in this paper was funded by Sandia National Laboratories.

The battery design contains a nickel burst diaphragm which functions as a safety vent under abusive extremes of temperature and pressure. The vent is designed to release internal pressure when the diaphragm deflects into a sharpened lance at a preset internal pressure. Overall battery dimensions are 2.2" high x 3.14" in diameter and the unoptimized battery weight is approximately 2.25 pounds. All structural components are 316L stainless steel and hermeticity is achieved through TIG welded construction. Glass-to-metal seals and a safety vent are provided within the terminal place housing.

Figure 2 is a photograph of an assembled battery after fabrication.

SAFETY TEST PARAMETERS

Prototype batteries have been assembled and successfully discharged to a specified load profile across the temperature range of interest (32°F to 111°F). In addition, a series of five (5) batteries have been subjected to abusive safety testing. Safety characteristics were evaluated under the following conditions:

- A - Short circuit of a freshly activated battery at +70°
- B - Short circuit of a partially discharged battery (discharged through one profile) at +70° C
- C - Short circuit of a battery discharged through one profile at -40° C and then heated to +70° C prior to shorting
- D - Reverse discharging of a battery previously discharged through one cycle of the profile at 22° C, then heated to +70° C and discharged into reversal under a 2 amp constant current
- E - Charging of a fresh battery activated at +70° C and subsequently charged at 0.2A, 1.0A and 2.0A rates.

TEST FACILITY

The above described testing was conducted in the special test laboratory at Honeywell Power Sources Center. Test responsibilities include both acceptance and development testing. All testing is done to written requirements and with calibrated equipment traceable to the National Bureau of Standards.

Encompassing 5300 sq. ft., the lab is comprised of three major areas:

- Temperature and humidity testing, non-hazardous discharge and storage.
- Small cell hazard testing and postmortem <20 Ahr.

- Large cell hazard testing and discharge on units >20 Ahrs.

Testing conducted uses either hard wired permanent test stations designed and built by us or soft wire temporary test setups.

Test capabilities within these areas include:

- Temperature -70°C to $+230^{\circ}\text{C}$, constant, cyclical and programmable
- Resistive and current testing to 250A, constant and pulse
- Load timing to 3 ms (computer controlled)
- Humidity and temperature, constant and cyclic
- Data acquisition via chart recorders, analog and digital oscilloscopes, data loggers and computers (mainframe and desk top)
- Vibration - sinusoidal, small cells
- Drop testing - half sine and trapezoidal
- Computer control and monitoring of chamber temperature with shutoff control and off-site monitoring 24 hours a day.

FACILITY FOR ABUSE TESTING

All abuse testing is conducted in the Special Test Lab (STL). The STL has a floor space of 30' x 40' with about 24,000 ft³ volume. The room is equipped with an air "scrubber" tank. The tank is charged with a sodium hydroxide and water solution. Room air is drawn through a spray of the solution at 2000 cfm to an outside exhaust. This minimizes airborne pollutants to the outside of the STL and building.

There are ten environmental temperature chambers designed to reduce the effects of explosions. These chambers (Figure 3) are capable of controlling the operating temperature between -60°C and 120°C . They have been tested successfully by heating to destruction of fresh Li/SOCl₂ cells as big as 500 Ah capacity and were designed to handle cells to 1000 Ah capacity.

The room is instrumented via ports through the walls. The area has restricted access during safety testing. Whenever there is a potential safety hazard, personnel entering the area must have Safety Committee approval, use respirators as needed, and must be assisted by at least one other person (buddy system) before entry. All test chambers are computer monitored with limit-sense for alarm. Alarm coverage is provided 24 hours per day. The alarm may be analyzed from a remote terminal which allows rapid assessment of the problem. Temperatures are scanned every 10 minutes and recorded and printed once every four hours.

TEST RESULTS

As would be expected, the battery vent functioned effectively during the short circuit test of a freshly activated battery and during the charging test of a freshly activated battery. The three remaining units from which a portion of the capacity had been removed prior to abusive testing did not vent during abuse but did exhibit heating and slight-to-noticeable deformation. None of the tests demonstrated "violent" reactions; i.e., exploding under any of the above abuse conditions.

Data associated with the charging of a fresh battery activated at +70°C and subsequently charged at 0.1A, 1.0A and 2.0A rates until battery venting was achieved is presented in Figure 4. This data is representative of the most severe conditions noted during the series of 5 abuse tests. The graph shows that a battery rise time of slightly under 70 ms was recorded to reach the 12.0 volt level. This is typical for reserve batteries employing this design concept.

During the 0.1A charge, the battery temperature stabilized at 75°C, while the battery voltage climbed steadily initially and then stabilized slightly over 20 volts.

The charging current was then increased to 1.0A with a resultant increase in battery temperature to 88°C prior to stabilization. The charging current was then increased to 2.0A level which resulted in a rapid rise in battery temperature from 88°C to 92°C within a five-minute interval. At this point, the battery safely vented. A peak temperature of 104°C was recorded two minutes after venting.

After the completion of the series of five (5) safety/abuse tests, the batteries were disposed of in the STL via puncturing each unit hydraulically under water. Figure 5 depicts the units after piercing and removal from the hydraulic fixture prior to disposal.

SUMMARY AND CONCLUSIONS

A reserve Lithium-Thionyl Chloride Battery concept has been developed and is currently undergoing feasibility testing in terms of performance, safety, and abusive conditions. The objective of this testing is to demonstrate the feasibility of employing a battery of this type to replace thermal batteries in certain applications.

In summary:

- o Excellent performance of a Li/SOCl₂ reserve battery has been obtained across the temperature range of interest, 0°C to +44°C.
- o Performance improvement over the thermal battery usage is greater by a factor of 3 when discharge time and energy density are compared.

- o Performance over an expanded temperature range is also possible; for instance, at -40°C , satisfactory performance was demonstrated against typical thermal battery specifications.
- o Safety and abusive testing was successfully accomplished on a series of five units. This series of tests did not reveal any abnormal condition due to the abusive nature of the tests performed. The battery vent functioned effectively during fresh short circuit and during battery charging. Three remaining tests did not vent during abuse, but did exhibit heating and slight deformation. None of the tests demonstrated "violent" reactions; i.e., exploding, under any condition of abuse.
- o Further performance improvements can be achieved with additional development, particularly with regard to battery weight and volume reductions.

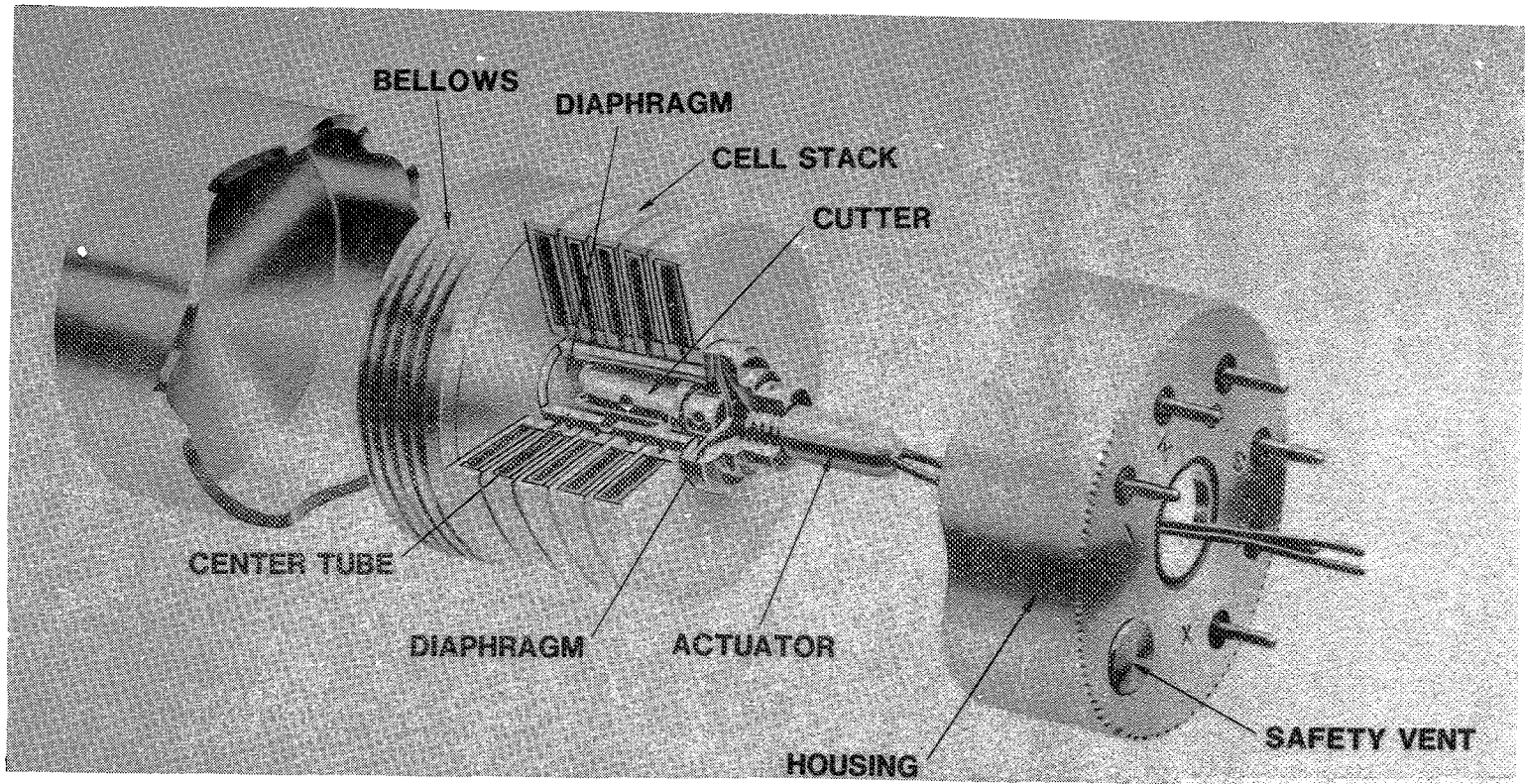


Figure 1. Reserve Lithium/Thionyl-Chloride (RLTC) Battery

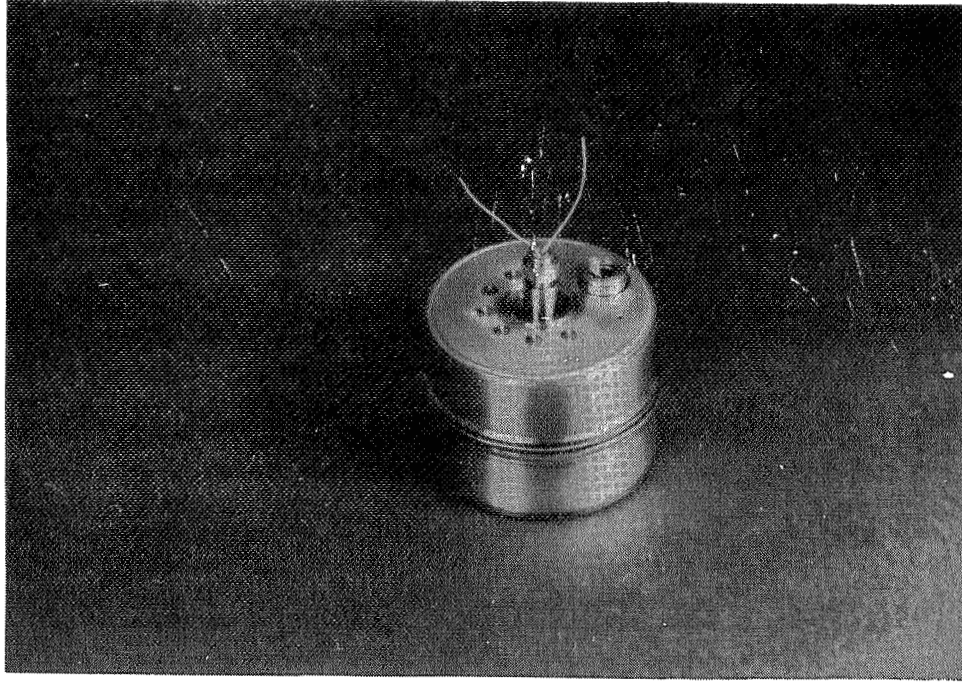


Figure 2. Assembled Li/SoCl₂ reserve battery.

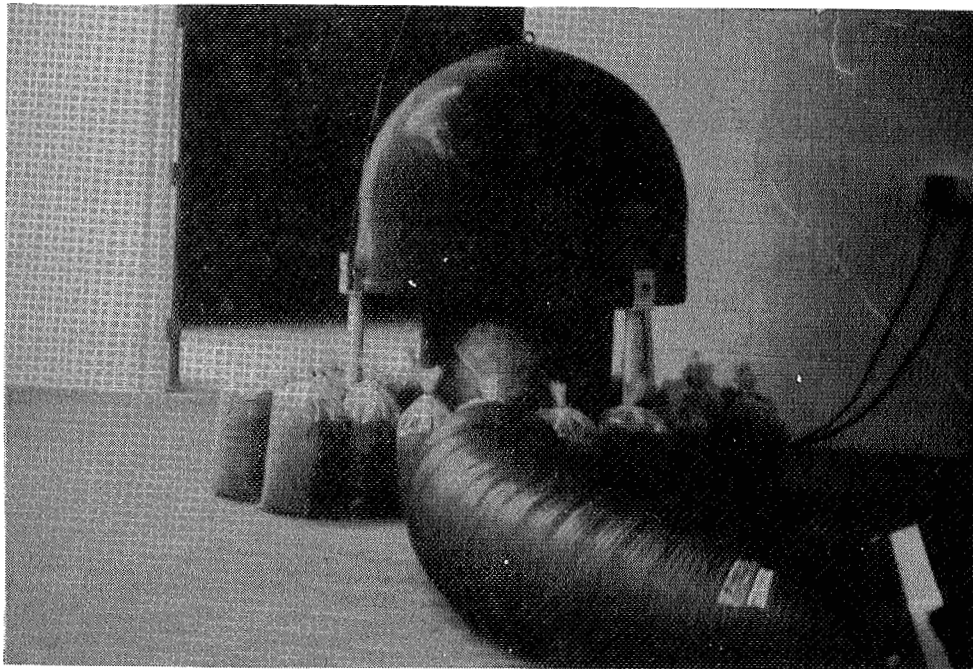


Figure 3. Special test laboratory test setup.

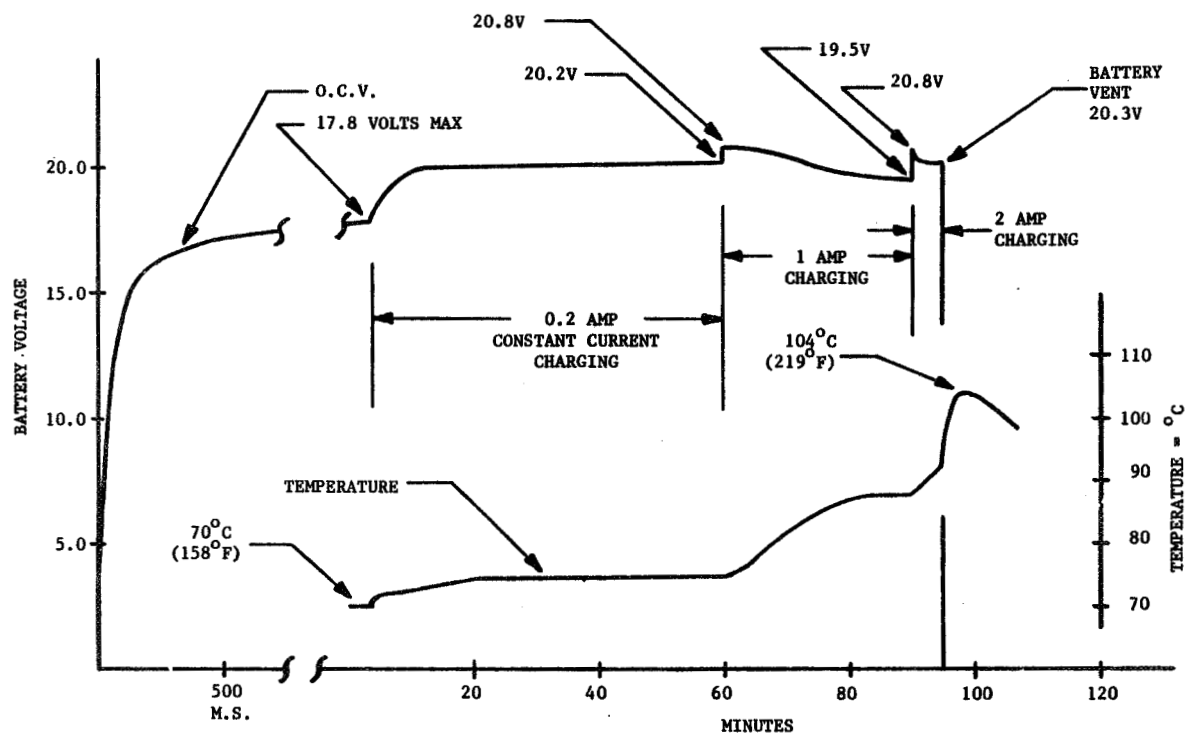


Figure 4. Constant current charging test at 70°C.

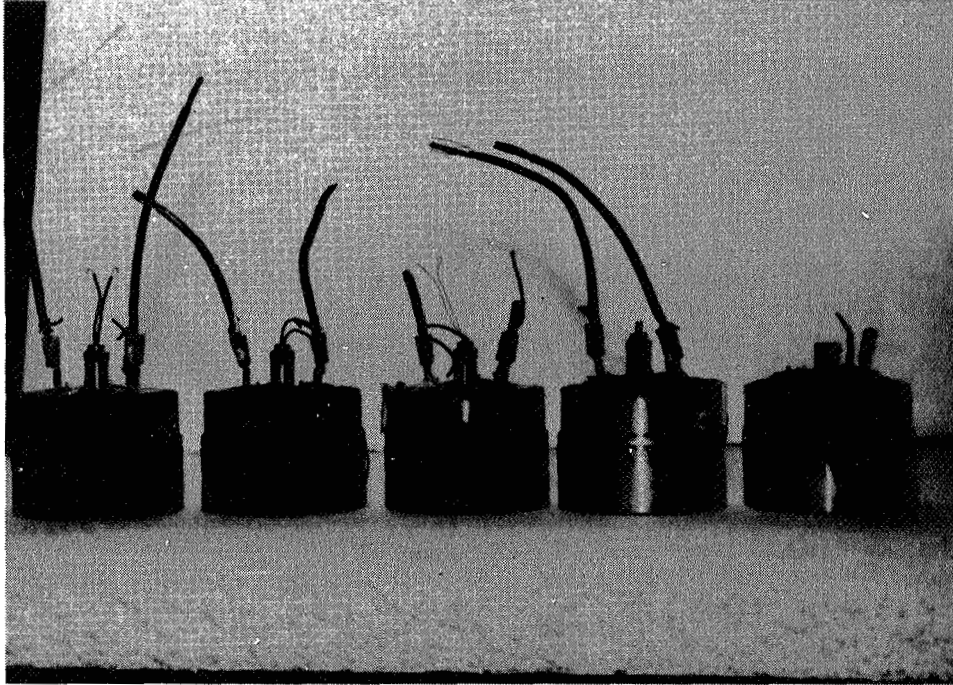


Figure 5. Safety/abuse test units prior to disposal.

- Q. Roth, NASA HQ: I was wondering, in any of these tests, did you try to find out what the toxic constituents are that came off? And the reason I asked that question is some people take certain measurements and not others and what I guess I don't see is any across the board systematic approach to all these where everybody is tending to try to get the same data so that they can pass it among each other.
- A. Dils, Honeywell: We did not analyze any of the gasses off of these tests. There has been work done there. I can't discuss it. Maybe Dr. Chua would have some information.
- A. Chua, Honeywell: There have been some analysis and basically the result is consistent with what Dr. Barnes percent is - basically hydrochloric acid and sulfur dioxide. The analysis was not on the particular set but on another program. It's basically SO₂ and hydrochloric acid - the major gas species.
- Q. Roth, NASA HQ: Yeah, I guess the thought in my mind was looking at the other percentages - parts per million and that sort of thing - to see if it varies cell to cell or type to type.
- A. Chua, Honeywell: That's hard to say.
- A. Barnes, NSWC: In response to the question of safety - there certainly is a great deal of variability depending on how the cell is opened and whether or not the cell has been partially or fully discharged or whether it's a fresh cell. So that, yes, you do get a lot of variability depending on what regime you decide to run for your test program.
- Q. Felder, General Electric: I think I must have missed it. What's the application of these batteries?
- A. Dils, Honeywell: They were being evaluated against a thermal battery application.
- Q. Felder, General Electric: For what? What application?
- A. Dils, Honeywell: I can't answer that.
- Q. Levy, Sandia National Lab: Since some of those cells vented in some way other than they're normally supposed to, is there anything in that battery design that could possibly have blocked off the safety vent?
- A. Barnes, NSWC: Not that we could find. We took one battery pack apart and it was as typical of low production battery packs made from standard cells held together with glue and shrink wrap. It was not heavily potted or anything like that.