

## Short Communication

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# Mechanism of explosions of Li/SOCl<sub>2</sub> power sources

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### Abstract

A short account of an experimental study of the safety performance conditions for powerful Li/SOCl<sub>2</sub> series batteries is reported. The data obtained suggest a mechanism for the sporadically-occurring explosions within the batteries. Pressure build-up, preceded by battery self-heating, leads to the seal failure which is accompanied by an eruption of the cell contents. An arising cloud of highly-active lithium dust then favours the conditions required for an especially destructive bulk explosion.

### Introduction

The growing application of powerful Li/SOCl<sub>2</sub> cells is currently limited because of explosions occurring sporadically [1]. The nature of these explosions has not received sufficient experimental study. Theoretical explanations of this phenomenon commonly involve conceptions developed in the classical theory of thermal explosions. Our experimental study of safety performance for commercial Li/SOCl<sub>2</sub> power sources has enabled a different mechanism for the phenomenon to be considered.

### Previous conceptions

Our previous idea was, naturally, that an electrothermal explosion in the cell was due to an imbalance between heat generation, accelerating with temperature, and heat losses. In simplified mathematical terms, the corresponding heat-balance equation has a steady-state solution only in the range of very high temperatures. So, to solve the problem we had therefore to establish experimentally the shape of the heat-generation function and to determine the constants involved. Knowing the formal kinetics of heat generation would then enable phenomenological relationships in order to estimate, a priori, the safe performance of cells with respect to the ambient temperature, continuous performance, and load power.

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## Experimental technique

Our subsequent experimental studies were to confirm the available theoretical ideas and to enable the real values of the parameters involved. To specify the type and parameters of the heat generation rate, both the thermograph technique, widely employed to obtain effective values of chemical reaction constants, and recorded voltage-current curves were used.

The main experimental task was to establish the temperature changes in the cell, depending on time at various loads. The temperature was measured with thermocouples whose hot junctions were placed between the battery elements, with cold junctions being at ambient temperature. The cell temperature was recorded with electronic automatic potentiometers. The current changes in the circuit were recorded with an oscillograph. Also, a high-speed camera was used to record simultaneously the process.

The experiments were made with powerful commercial batteries at various resistive loads of the external circuit (from that corresponding to 'short circuit' to conventional).

## Observed data

Our experimental results have shown that the total internal heat generation in the cell, in the load range studied, remained practically constant throughout the performance and in most cases exceeded considerably heat losses to the environment. This results in the linear growth of temperature in the cell with time, which was observed in the absolute majority of our experiments. Breaking the circuit immediately resulted in cooling just like an inert body, indicating that the possible contribution of any other, exclusively chemical sources to the total heat generation could be, to say the least, negligible.

In a number of experiments, conditions were intentionally created to cause a cell 'explosion'. In all these cases the 'explosion' was immediately preceded by a short period of a much sharper ('explosive') temperature runaway. In our opinion, this unambiguously meant that inside the cell the melting temperature of lithium anode was attained, resulting in the destruction of the passivating LiCl film, which is accompanied by an increase in the reaction rates.

## Explosive behaviour

The 'explosions' observed involved three different types of physical phenomena: seal failure, ignition, and explosion proper.

The high-speed camera data have shown that the explosive behaviour always started in the same manner. Initially, a seal failure occurs in one (or several, possibly all) battery elements, which is accompanied by an eruption of the cell contents and the appearance of a large cloud.

Both self-ignition and explosion, following the seal failure, are not obligatory. The appearance of these highly-undesirable phenomena is largely determined by additional, often uncontrollable factors, the principal of them being the aggregate state of the lithium anode at the moment seal failure. Any liquid lithium is carried into the air in the form of highly-active lithium particles, which subsequently ignite. The size of the cloud determines whether this burning will proceed into an especially destructive bulk explosion.

Seal failure occurs when the threshold pressure depending on the case strength is attained. The cell pressure consists of thionyl chloride saturated vapour pressure and the partial pressures of gaseous admixtures and reaction products. The former is an unambiguous function of current cell temperature, and the latter depends on the gas amount and the volume occupied by gas. So, pressure in the cell can go up both as a result of a temperature increase involving an increase in the pressure of thionyl chloride saturated vapour and as a result of gas production during the reaction, with the second factor being quite significant when the gas volume occupied by gas is small. The volume of the gas bubble is a weakly-controllable parameter and introduces the observed randomness of the explosive performance.

## Conclusions

One can recommend the following ways of reducing the hazardous behaviour in the cells studied:

(i) taking smaller initial amounts of lithium in the cell, so that there is a minimum amount of melted lithium to be erupted into the environment if the seal fails;

(ii) providing (with an unidirectional restrictor valve) an operating pressure which does not exceed the pressure of thionyl chloride saturated vapour at the melting temperature of lithium.

Increasing the strength of the cell case is not useful in itself. Although it will lead to a greater threshold pressure at which leaktightness fails, the dispersion and the size of the cloud are also increased, favouring the condition for a bulk explosion.

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## References

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