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Development of a High-Temperature Rechargeable Battery for Downhole Use in the Petroleum Industry

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Abstract

The oilfield uses batteries to power an ever-increasing array of downhole tools. However, the options for batteries that will maintain integrity in high-temperature environments are limited primarily to primary (non-rechargeable) lithium batteries. While these high-temperature lithium batteries have a high energy density, they require controlled disposal after use, and there are concerns about their safety.

The petroleum industry has recognized the need for battery chemistries other than lithium primary batteries. Standard room-temperature-type batteries require temperatures cooler than those found in downhole petroleum reservoirs to operate. On the other hand, thermal batteries require temperatures that are significantly hotter than those found downhole. Therefore, other than lithium primary cells, to date there have not been other good battery chemistries for downhole temperatures. Similarly, there have not been good options for rechargeable oilfield batteries available to the industry.

This paper describes the development of a new type of rechargeable battery chemistry. This molten salt rechargeable battery operates from room temperature to 130°C and survives to 150°C. The battery can be charged and discharged throughout this temperature range. Field tests with the molten salt rechargeable battery have been conducted with a battery-operated electro-mechanical slickline power unit.

Introduction

The electronics in downhole oilfield tools need electrical power. This electrical power typically is delivered by electric line or is stored in the form of batteries. The market for downhole batteries within the oilfield has been dominated by primary lithium batteries, as they are characterized by having one of the highest energy densities and one of the highest cell voltages of practical, commercially available battery systems¹. However, there have been concerns with primary lithium batteries due to safety issues as well as operational concerns due to passivation. These safety issues have been driven by the hazardousness of some of the internal components, where some of the internal components are toxic and flammable.² The relatively low melting point of lithium (180.5°C) requires careful control of discharge currents to prevent the internal temperatures from melting the lithium, which could cause a dangerous venting reaction and thermal runaway reactions. As a result, primary lithium batteries are designed to limit their output current. Short circuiting a primary lithium battery will typically break an internal fuse within the battery in order to prevent dangerous overheating.

Primary lithium batteries for the oilfield are designed to passivate the lithium anode. Passivation is an action in which a chemical film forms on the electrode of the lithium primary batteries. The passivation layer is needed to protect the electrode from the chemically aggressive electrolyte and is necessary to prevent rapid self-discharge of the primary lithium battery. Passivation can be a problem, because this chemical film increases the internal resistance of the lithium battery and must be removed by running a current through the battery.

Traditionally, there have been few alternatives for the oilfield other than primary lithium batteries³. Most room-temperature battery chemistries, such as room-temperature lithium-ion batteries, will not operate over 50°C to 60°C⁴ because of increased internal pressure and also because the chemistries are unstable at the combination of elevated temperature and voltage difference. This chemical instability quickly will lead to either an oxidation or reduction reaction as well as a thermal runaway reaction that will drain the voltage and capacity from the battery. Thus, none of the currently available batteries would be appropriate in their current forms.

In order to develop a rechargeable downhole battery that would meet the current needs for operation at higher temperatures, it was necessary to change the chemistry of an existing technology.⁵ The battery that seemed most appropriate for this endeavor; i.e., a high-