Thermal Study of Valve Regulated Lead Acid Batteries and Electronics Chamber Used in Stand-Alone Street Lighting Applications

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Abstract

PoleCo is a firm based in Nova Scotia, Canada, which supplies stand-alone street lighting systems. These street-lights are powered by renewable sources, such as solar panels, and thus rely on rechargeable lead-acid batteries to store energy during the day. The lifetime of these batteries is highly dependent on their operating temperature; in general a 10 °C increase in temperature will reduce the lifetime of a lead-acid battery by half. Due to the expense of replacing these batteries, PoleCo is interested in the heat generation characteristics of the batteries used in their street-lights, as well as potential strategies that could be used to keep the battery temperatures lower. To that end, PoleCo and the Dalhousie Lab of Applied Multiphase Thermal Engineering (LAMTE) are collaborating to investigate the thermal properties of these batteries.

COMSOL Multiphysics® software is used in this project to test heat generation equations by comparing numerical models with experimental results. The simplest of these models is a battery surrounded by insulation and charged at a set rate. In COMSOL, the battery is represented by a rectangular prism with homogeneous material properties and uniform heat generation throughout the volume (Fig. 1). Along the surface of the rectangle are boundary point probes in positions analogous to the locations of thermocouples on the actual battery. The initial conditions of the model are set to match the experimental data, and the heat generation of the simulated battery is set to the function that is being tested. The results from the boundary point probes are then compared with the data from the thermocouples (Fig. 2). The results from these simulations show that it is possible to match experimental data almost exactly with the simple COMSOL model of the battery and surrounding insulation. This allows us to confirm that the heat generation within the battery can be predicted by a mathematical function of the current and voltage measured at the battery terminals.

COMSOL is also used to simulate more complex experiments involving natural convection inside a chamber containing multiple batteries and other auxiliary equipment (Fig. 3). By correlating COMSOL models with experiments, a very accurate picture model describing heat generation and heat transfer, including natural convection, within the chamber is validated. Regions of natural convection can be shown in COMSOL graphs of the model (Fig. 4). In addition, this model is used to simulate the effects of external conditions on the system

surrounding the batteries, such as those presented by warm climate, sunny conditions or by forced convection via fans, in order to determine temperature control strategies that could be implemented in the future.

Figures used in the abstract

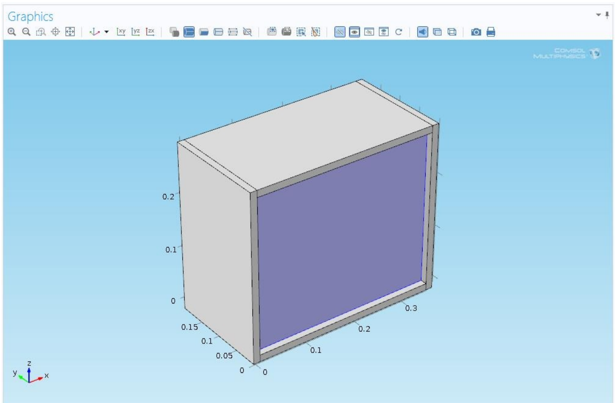

Figure 1: COMSOL model of lead acid battery and insulation.

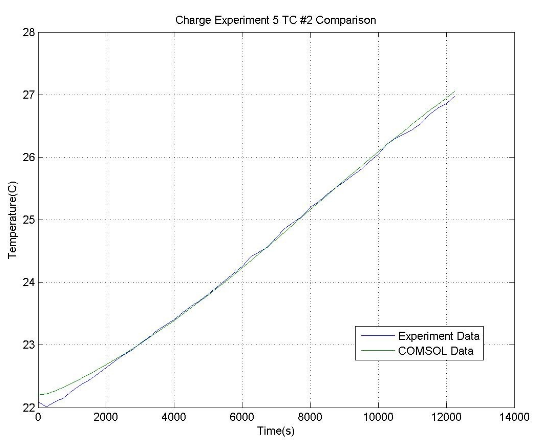

Figure 2: Comparison of experimental temperature reading with COMSOL simulation.

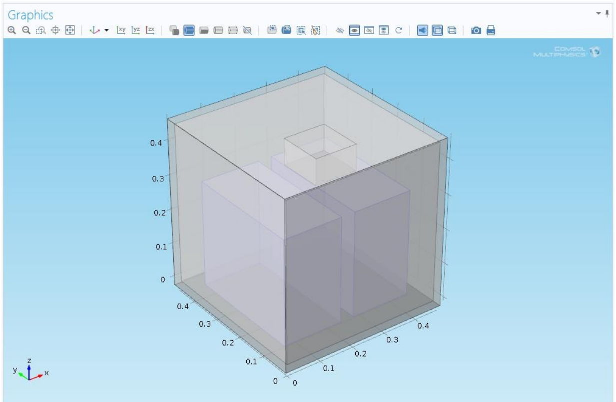

Figure 3: COMSOL model of enclosure with two batteries.

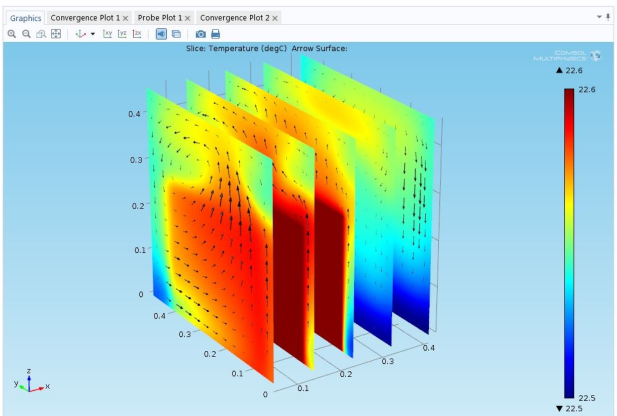

Figure 4: COMSOL plot of convection plume above single battery within enclosure.