Design and Prototyping of a Passive Cold Chain Vaccine Storage Device for Long Hold Times

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Abstract

In 2010 an estimated 109 million infants were immunized against DTP, which serves as a good proxy for vaccinations in general. At the same time, however, approximately 19.3 million infants worldwide were not reached by routine DTP immunization services. Immunization rates tend to be lowest in areas where poor infrastructure and limited access to electricity can cause vaccine stock-outs and high wastage rates. Recently, the growth of larger volume and more costly vaccines has added strain to the already inadequate cold chain infrastructure in the developing world. To address these challenges, the Intellectual Ventures Laboratory (IVL) has been developing a passive vaccine storage device (PVSD) -- an insulated container that keeps vaccines cold without any external cooling -- that will expand the uninterrupted supply chain of vaccines to the remotest parts of the developing world. The PVSD is designed to overcome infrastructure and logistics barriers by storing vaccines at appropriate temperatures for more than a month using a single initial supply of ice.

The IVL PVSD achieves an order of magnitude improvement on existing vaccine cold chain PVSD storage times by integrating various high-performance technologies into a rugged and user-friendly package. Radiative heat leakage is minimized through the use of a vacuum chamber and insulation technology. Conductive heat leakage is minimized through a low-k port sized for easy access by hand. Inside the IVL PVSD, vaccines are arranged efficiently alongside ice containers.

To get from design requirements to functioning prototypes in the field, IVL has leveraged thermal modeling at a range of resolutions. In this presentation, we examine scenarios where COMSOL has uniquely aided the design team's understanding of thermal performance tradeoffs against various critical design parameters and use scenarios. In particular, we present results from models of transient heat and momentum transfer in various IVL passive vaccine storage device prototypes. These models employ analytical approaches to simulate the performance of our advanced insulation technology, and the enthalpy method to track the melting of ice under different design configurations and use scenarios. Experimental approaches for validating model predictions are discussed with a focus on the challenges present when balancing model rigor and accuracy against the need for a nimble design support tool.

Figures used in the abstract

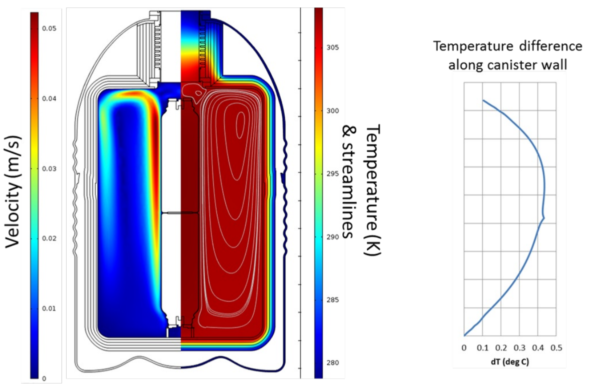

Figure 1

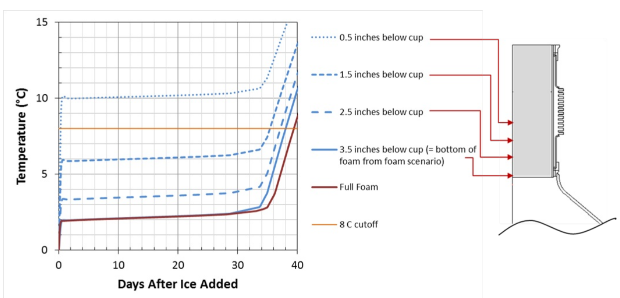

Figure 2