EXPERIMENTATION AND MODELING OF PIEZOELECTRIC-BASED ULTRASONIC ACOUSTIC-ELECTRIC CHANNELS

By

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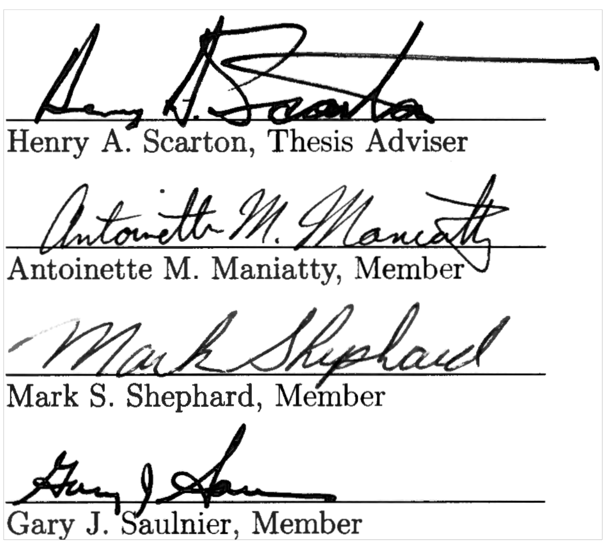

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ABSTRACT

Passing of electrical signals, which may include power, data, or both, through metallic vessels has typically been relegated to mechanical penetrations through the vessel's wall. These ingress points introduce structural integrity issues, as well as a possible avenue for the isolated environment to be contaminated through sealing failure. Alternative methods for conveying the signals through the barrier as acoustic waves would be incredibly beneficial as these risks may be mitigated. This thesis considers a system composed of piezoelectric transducers which uses ultrasonic waves to transmit the electrical signals through the barrier without compromising the vessel's integrity. The fundamental operation of the system is presented with a focus on the power transfer efficiency. Methods for attachment of the required transducers to the barrier are introduced for both room temperature and elevated temperature operation. Two methods of modeling these systems, which are referred to as "acoustic-electric channels," are discussed: a one-dimensional, quasi two-dimensional, analytical model is developed along with a two-dimensional axisymmetric finite element model. These models are validated against measurements of test channels and are shown to be accurate. Implications on the power transfer efficiency of various design criteria are drawn from extensive model evaluations. Experiments on the high-power operation of two channels are presented, showing the channels to be capable of transmitting upwards of 140 W of AC power through a 57.2 mm stainless steel test section with power transfer efficiencies greater than 60 % using only 25.4 mm diameter transducers. Extrapolation of these results to larger channels predicts kW operation to be highly feasible. High-temperature experiments are also presented, showing channel operation capable at temperatures up to 260°C (500°F). Using the developed models, temperature dependent material properties for the channel's components are extracted and employed to predict the high-temperature operation of channels with varying configurations.