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An Innovative Monitoring Technology for the Reactor Vessel of Micro-HTGR

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ABSTRACT:

The proposed project will support the goal of the Advanced Sensors and Instrumentation (ASI) program to "develop dynamic measurement systems for structural health monitoring of advanced reactors." This project demonstrates the use of existing sensor technology while enhancing the predicting capabilities using computational fluid dynamics (CFD) and machine learning (ML). The team will leverage recent advances in both ML based field reconstruction techniques and diagnostic software to augment traditional sensor capabilities. We will develop and demonstrate an integrated sensor technology for real-time monitoring of thermal-mechanical stresses of the reactor vessel of micro-high temperature gas reactors (mHTGRs). The proposed technology will provide (1) a real-time, reliable and cost-effective monitoring methodology, (2) a quantification of the lifetime and integrity of the pressure vessel of the mHTGR, and (3) a means to improve the economics of the microreactor systems. The team is well-positioned to develop and demonstrate the monitoring system with expertise in physical measurements, high fidelity numerical simulations, and machine learning.

The proposed program consists of four (4) tasks, completed over three years, leading to the development and demonstration of the integrated monitoring system. Task I: The project will begin with a detailed literature survey and initial data collection. Based on the literature review and input from the industry partner, expected operating and accident conditions will be identified. Task II: A CNN-based field reconstruction algorithm developed at Argonne will be modified and optimized for the proposed project. The existing algorithm will be expanded to incorporate the operating conditions identified in Task I and predictive capabilities based on PRO-AID. The ML algorithm will produce temperature and pressure fields, and this will be coupled with a finite element method (FEM) solver to provide thermal-mechanical stresses on the reactor vessel. Task III: The use of the algorithm to predict thermal-mechanical stresses in the vessel wall will be demonstrated in this task. Experiments will be completed in an existing facility using a variety of measurement techniques. The experiments will provide a foundation of data to train the ML algorithms. Using the output from Task II, the optimal location of sparsely placed sensors will be identified. Tasks II and III will occur in parallel. Task IV: With the conclusion of the project, a final report will be prepared detailing the use of sensors, validation results, and suggestions for future deployment.

The primary deliverable of this project is a novel, non-intrusive sensing technology for real-time monitoring of the thermal-mechanical stresses in the reactor vessel of a mHGTR. Details of the sensor technology, ML algorithms, and validation results developed and obtained in this project will be made available. The technology developed in this project will be a tool capable of structural health monitoring of advanced reactors. The system will build on existing technology and thus create an economical tool to quantify the life of reactor components.