3-D Chemo-Mechanical Degradation State Monitoring, Diagnostics and Prognostics of Corrosion Processes in Nuclear Power Plant Secondary Piping Structures

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ABSTRACT:

The Light Water Reactor Sustainability program is working to extend the life of commercial light water reactors beyond the current 60-year licensing period by developing and deploying online monitoring systems for addressing high maintenance costs and potential forced plant outages. Passive metallic structures in Nuclear Power Plants (NPPs) – such as pressure vessels and piping for primary and secondary cooling systems – are tremendously challenging and costly to maintain. This will be as true for new small modular reactor designs in next generation plants as it is in today's plants. Degradation mechanisms like Stress Corrosion Cracking, General Corrosion, Erosion-Corrosion, and other corrosive mechanisms in secondary piping are driven by metallurgical, chemical, and operational parameters and pose a particular safety concern because personnel are often in close proximity to cooling circuits. Although Nondestructive Inspection techniques like Ultrasonic Testing and Radiography Testing are conducted by removing insulation during refueling outages, these inspections are cost intensive and do not provide a continuous 3-D assessment of the chemo-mechanical material state (diagnosis) or its evolution (prognosis) as in the case of corrosion damage for which the chemistry drives the process of oxide production followed by material loss, cracking, and the potential for exceeding structural performance limits.

To address these cross-cutting needs in current and future NPPs, the proposed research will develop a generalizable 3-D sensor network for the chemo-mechanical degradation state monitoring, diagnostics and prognostics of corrosive processes in representative secondary pipe structures. The outcome will be a 3-D sensor mesh network and optimized set of algorithms for mapping in three dimensions both mechanical degradation and the onset of such degradation via chemical processes such as corrosion. The novelty of these outcomes is found in the ability to sense using thermoelectric energy conversion supplied by the operating cooling circuit; the ability to diagnose damage due to the all-important chemical processes that drive oxide formation and degradation, as well as material loss in piping structures in NPPs; the ability to detect such chemo-mechanical material state degradation using smart layers to observe the chemical processes which are otherwise not visible from the surface of a structural component; and the incorporation of Bayesian networks for optimizing such sensor networks and algorithms as a structural health monitoring system to enable NPP monitoring.