Development of Cable Aging Acceptance Criteria for Nuclear Facilities

Principle Investigator:

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Program: DOE-FOA-0001817 Pathway II

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ABSTRACT:

A. Project Description

Over time, exposure to harsh environmental conditions such as elevated temperatures, radiation, and humidity in nuclear installations can result in age-related degradation and failure of cables. In the current fleet of nuclear reactors, there are thousands of miles of cabling, many of which are exposed to harsh environmental conditions. For these cables, the jacket and insulation polymers harden and become brittle, making them more susceptible to crack formation and growth, moisture intrusion, and other mechanisms that can lead to cable failure. Moreover, the existing U.S. fleet of 99 nuclear reactors is aging with the average age of operation being 37 years. A majority of these nuclear power plants have applied for license renewals to operate beyond their original 40-year life for 60 years and almost all have been granted regulatory approval to extend their life. Further, a second license renewal referred to as subsequent license renewal or SLR is underway with a few nuclear sites already in the process of applying to operate up to 80 or more years. As these reactors pursue operating life extensions, the utilities must find a way to address issues associated with age-related degradation of cables. Designers of small modular reactors and advanced reactors are also in need of technologies that can be used to assess the performance of cables that will be installed in harsher environments (e.g. higher temperatures, radiation doses, humidity, etc.) than those in current generation of nuclear reactors.

The purpose of the proposed research collaboration between Analysis and Measurement Services Corporation (AMS) and researchers at Oak Ridge National Laboratory (ORNL) and Pacific Northwest National Laboratory (PNNL) is to develop acceptance criteria for mechanical, electrical, thermal, and chemical condition monitoring (CM) tests that trend with age-related degradation of electrical cables. The work to be performed under the project includes subjecting cables to thermal accelerated aging, radiation exposure, and periodic testing using CM techniques to trend their properties as they age. After the cable samples have been subjected to thermal and radiation aging, they will then be exposed to loss of coolant accident (LOCA) conditions to determine their point of failure. These LOCA test results will be used in conjunction with the CM data collected during the aging process to develop acceptance criteria that directly correlates with the end-of life-condition of a cable polymer.

B. Scope of Work and Project Objectives

The goal of the project will be achieved through a hands-on collaborative R&D effort between AMS, ORNL, and PNNL involving laboratory measurements and analytical work. The following is a list of the project objectives that will be completed as well as key technical tasks that will be accomplished under each objective:

Objective 1: IDENTIFY AND ACQUIRE CABLES FOR AGING

- Cables will be acquired from either cable manufacturers or utilities.

Objective 2: CORRELATE CM RESULTS WITH LEVEL OF THERMAL AND RADIATION AGING DEGRADATION

- AMS will perform baseline CM testing, thermal accelerated aging, and periodic CM testing throughout the project to trend CM tests with thermal aging.
- PNNL will perform radiation exposure and AMS will perform periodic CM testing to trend CM tests with radiation aging.

Objective 3: PERFORM LOCA EXPOSURE AND WITHSTAND TESTING OF AGED CABLES

- ORNL will perform LOCA exposure and post-LOCA withstand testing to determine the cables' end of life.

Objective 4: DEVELOP ACCEPTANCE CRITERIA FOR EACH CM TEST

- AMS will correlate the CM data with the LOCA test results to establish acceptance criteria.

Objective 5: DETERMINE APPLICABILITY OF CM DATA TO REMAINING USEFUL LIFE ESTIMATES

- AMS will use the empirical data from cables aged to end of life to determine if Arrhenius method can be applied to the CM data to estimate the remaining useful life (RUL) of cable polymers.

Objective 6: SHARE THE RESULTS WITH THE INDUSTRY

- The project team will share the results with nuclear industry experts including utilities, researchers, and regulators to provide an objective means to assess the condition of cables.

C. **Project Outcomes and Deliverables**

The successful completion of this project will produce quantitative cable aging acceptance criteria that can be used by the U.S. nuclear facilities and other industries worldwide to assess the in-service aged condition of the most commonly used insulation polymers. The CM technologies will be used by current generation nuclear power plants as well as small modular and advanced reactors to: 1) objectively determine the condition of installed plant cables, 2) estimate when the cables will reach their end of life, and 3) help determine which cable polymers are suitable for operation in harsh environments. This type of work is needed to:

- Support cable aging management programs in the nuclear industry by providing the means to verify the health and performance of cables, which is needed to support subsequent license renewal (SLR) approval.
- Identify aged or degraded cables before they cause operability issues in facilities including nuclear power plants, research reactors, nuclear fuel processing and fabrication facilities, and nuclear waste disposal plants.
- Avoid unnecessary and costly replacement of cables that can continue to operate safely and reliably.
- Assist in the selection of cables that will be used in the next generation of reactors.

The CM technologies developed under the project will be integrated into AMS's existing services to provide test equipment and trained personnel to perform on-site and laboratory aging evaluations and RUL estimations of installed cables. The results of this R&D effort will be provided to DOE in quarterly progress reports as well as a comprehensive final report at the conclusion of the project.