Experimental Verification of Post-Accident Integrated Pressurized Water Reactor (iPWR) Aerosol Behavior, Phase 3

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Collaborators: Electric Power Research Institute, Pittsburgh Technical, Carnegie Mellon University, Jensen-Hughes, LPI, NuScale Power, TVA

ABSTRACT:

In partnership with the U.S. Department of Energy, the Electric Power Research Institute (EPRI) recently completed a multi-year effort to model and estimate the in-containment post-accident radionuclide aerosol concentration levels for integrated pressurized water reactors (iPWRs).
Under assumed severe accident conditions, a nuclear reactor's containment vessel (CV) is designed to provide a defense-in-depth function for preventing radionuclide particle release. This is achieved by creating a physical barrier and by decontaminating aerosols produced during the accident. Decontamination occurs through active mechanical systems (where applicable) and passive naturally-occurring phenomena. Due to their comparatively higher containment surface-area-to-volume ratios when compared to large light water reactors (LWRs), the iPWR subcategory of small modular reactors (SMRs) has design features that increase the passive decontamination factors due to an increased significance of naturally-occurring phenomena: gravitational settling, thermophoresis, diffusiophoresis, and impaction from convective flows.

The purpose of these prior EPRI studies has been to provide estimates for the decontamination associated with these phenomena. Specifically, EPRI's recent results provide decontamination factors associated with the thermal-hydraulic and geometric parameters that characterize iPWRs, based on experimental work which included the development and use of a novel experimental test system designed to model a range of iPWR designs at near accident temperatures and pressures, and associated computational fluid dynamics (CFD) modeling tools to test theories and calibrate against experimental results.

The most recent results indicate a potential for significant improvement in decontamination factors for iPWR designs, nominally showing that the decontamination factors for iPWRs without sprays are in line with the decontamination factors for large light water reactors with sprays, and about five times greater than prior calculations would show for iPWRs. These results are documented in EPRI report *Advanced Nuclear Technology: Integrated Pressurized Water Reactor (iPWR) Containment Aerosol Deposition Behavior: Phase 2b: Results and Analysis*, EPRI 3002013032, March 28, 2018.

The objective of this new project, Phase 3, is to further improve the models used to estimate the post-accident radionuclide concentration levels for iPWRs. By improving estimation models, iPWR designers will have a better understanding of containment vessel radionuclide particle retention capabilities for post-accident conditions. This project will provide a tool for current and future iPWR designers, as well as those siting new plants, by demonstrating potentially lower source-terms.
EPRI will expand upon the recent research to address additional questions that can improve current modeling capabilities. These additional research topics were collectively identified by the Nuclear Regulatory Commission (NRC) and an iPWR designer as additional areas for research, and as outfalls of the recently completed work.

- Characterize the expectation for re-entrainment / resuspension
- Assess the significance of particle agglomeration / coagulation

- Characterize impaction at various locations
- Assess the effects of non-uniform distribution of particles in the containment vessel
- Assess the effects of transient aerosol concentrations during pressurization
- Assess effects of vertical temperature gradients on the CV and reactor vessel (RV) walls
- Characterize the effects of a reduction in containment vessel pressure
- Characterize the effects of a sudden increase in pressure due to latent aerosol burst into the containment vessel
- Assess the significance of an uninsulated vessel top relative to the experimental configuration and results
- Assess the effects of larger particles (>10 μm) on deposition rates

The scope of this project is comparable to that of Phase 2. The major tasks are:

- Input will be collected from stakeholders to verify the plan, assumptions, and critical parameters for the project.
- The principal investigating team will then perform literature review and analytic analysis to help develop the overall testing plan. This plan will be vetted with stakeholders.
- Once this planning is complete the team will engineer the experimental hardware and develop the actual testing procedures. Prior to beginning testing, the team will vet the experimental plan with stakeholders one last time to help ensure the experimental testing is on track.
- The experimental testing will then be completed, followed by results analysis and reporting.

Deliverables:

- The key deliverable from this project will be an EPRI report describing the preliminary analysis, test plan, experimental results and final analysis.

The project team consists of the Electric Power Research Institute (EPRI), Pittsburgh Technical, Carnegie Mellon University, Jensen-Hughes, LPI, NuScale Power, and TVA. EPRI will provide overall project management, technical leadership, and manage production of R&D deliverables. Pittsburgh Technical will lead the test planning, experimental testing, and analysis. Jensen-Hughes and LPI will provide technical project management, augmented quality oversight, and third-party review. NuScale Power and TVA will provide input, advice, consultation and review throughout the project.

Successful execution of this project could provide numerous technical benefits, including:

- Simplification of onsite and offsite emergency response organization
- Potential reduction of on-shift staffing requirements
- Offsite fire/rescue/medical facility capabilities consistent with existing industrial hazard plans
- Potential reduction in number of participating agencies and jurisdictions
- Consolidation and simplification of emergency response facilities
- Offsite response and protective action strategy commensurate with the radiological risk

These results would bring benefits to the public, including:

- Lower operating costs, enabling new U.S. nuclear plants to compete in regional power markets
- Preservation of nuclear power as a fuel-diverse, base-load, carbon-free generation option
- Preservation of U.S. jobs at new nuclear plants and in supporting industries
- Opportunity to expand workforce via deployment of new reactor designs
- Opportunity to sustain U.S. leadership in nuclear plant technology and nonproliferation
- Improved nuclear safety