Prediction of Used Nuclear Fuel Cladding Temperatures under Vacuum Drying Conditions

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Abstract

Used nuclear fuel assemblies consist primarily of thin cladding tubes held in square arrays containing highly radioactive fuel pellets and fission product gases. After removal from a reactor, the assemblies are stored underwater while their heat generation and radioactivity rates decrease. After sufficient time, multiple assemblies are loaded into square openings within a canister. The canister is covered, sealed, lifted from the water, and drained while helium gas flows in. Most all of the remaining moisture must be removed to avoid corrosion or formation of combustible gases, before the canister is placed in other structures for onsite storage or offsite transport. To enhance evaporation and vapor removal, industry primarily uses vacuum drying, in which the helium pressure is reduced to as low as 67 Pa. At these low pressures, the helium within the canister’s small gaps reaches the slip-flow rarefied-gas regime. In this state, the temperature of heated surfaces is greater than gas in contact with the surfaces (this temperature jump is negligible when the gas acts as a continuum). This has the potential to increase the cladding temperature above certain limits, which may lead to future embrittlement, making fuel processing difficult. The goal of this work is to develop and experimentally validate computational methods that engineers can use to design drying processes that remove moisture, maintain cladding temperatures below safe limits, and minimize worker exposure. In this work, we use discrete velocity and direct simulation Monte Carlo simulations of rarefied dry helium between concentric cylinders to confirm Lin-Willis slip-flow temperature jump model. We perform concentric cylinder experiments to measure the accommodation coefficient between dry helium and stainless steel surfaces. We incorporate the validated properties and models into simulations of used fuel within a canister under vacuum drying conditions to predict the effect of low pressure on cladding temperatures. Finally, future work is described.

Dr. Miles Greiner received his Ph.D. from MIT in 1986, and joined the University of Nevada, Reno that same year. He is currently a Foundation Professor and Department Chair of Mechanical Engineering. He and his students have conducted research on used nuclear fuel packaging safety since 1993. Dr. Greiner is the Principle Educator of the UNR Graduate Certificate in Nuclear Packaging, which the DoE Packaging Certification Program supports.

This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.

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