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Metallic Fuel Relocation Experiments with Pressure Injection in a Pin Bundle Core Structure of a Sodium-Cooled Fast Reactor

Abstract: Dr. Taeil Kim is a principal nuclear engineer of Argonne National Laboratory. He is currently a principal investigator of sodium-cooled fast reactor safety experiment project. He received his Ph.D. in Nuclear Engineering in 2012 from Korea Advanced Institute of Science (KAIST). His dissertation was on the critical heat flux enhancement using nanofluids.

Biography: Argonne National Laboratory (ANL) and Korea Atomic Energy Research Institute (KAERI) agreed to Cooperative Research and Development Agreement (CRADA) to perform Sodium Fast Reactor (SFR) safety experiments and develop a simulation model for metal fuel relocation behavior in postulated severe accident conditions. In the project, first, the relocation behavior of the metallic fuel in single-pin core structures was investigated in order to study the relocation behavior in a narrow sodium channel. The single pin relocation (SPR) experiments showed that the injected uranium fuel is able to be fragmented and dispersed in a narrow coolant channel by sodium boiling. Afterward, the relocation behavior of the metallic fuel in a more prototypic pin bundle core structure was investigated. The pin bundle relocation (PBR) experiments showed that the more formation of the eutectics could lead to more fuel dispersion and less blockage due to the lower freezing point of the eutectics. The following pressure drop experiments confirmed that the sodium channel was not completely blocked, so there is a possibility of the coolable geometry formation of the relocated fuel in a severe accident. Currently, the relocation behavior of the metallic fuel in a pin bundle geometry has been investigated under more prototypic conditions by injecting the metallic fuels into the coolant channels with pressure up to 70 psig. In the first metallic fuel relocation with pressure injection (RPI-1) experiment, many fine fragments less than 1 mm were observed and these fine fragments can be attributed to the higher ejection velocity compared to previous SPR and PBR experiments. The visual inspection after the RPI-1 experiment confirmed that many of uranium levitated to upper plenum. It can be concluded that in the case of pressure injection, there is a possibility that uranium fuel can be quickly removed from the core region, resulting in a negative reactivity feedback effect. This negative reactivity feedback will help a SFR to terminate of the severe accidents.

Meanwhile, Argonne purchased an X-ray machine, Linatron M3a, for a real time X-ray video system as a DOE contribution of the ANL-KAERI CRADA. The X-ray system has a potential to record the process of fuel injecting and relocating in the coolant channel. It can potentially show us exactly when and how the molten fuel is injected into the coolant channel, how and in what extent the fragmentation and dispersion of the fuel occur. This information in conjunction with SAS4A simulations of the experiments will allow us to understand the fuel relocation behavior better, and this will lead to significant progress in severe accident code development and validation for SFR safety analysis. Currently, we are constructing the real time X-ray video system for the next metal fuel relocation experiment with pressure injection (RPI-2)a.

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