RFA-17-14611, SAS4A-FATE Code Integration

Source term assessment for the light water reactor (LWR) fleet involves deterministic analysis of radionuclide release due to a loss-of-coolant accident event among other initiating events. Since the primary coolant of a liquid metal cooled reactor (LMR) is kept at near atmospheric pressure and the margin to coolant boiling is greater than in LWRs, a loss-of-coolant accident event is not a concern for sodium fast reactors (SFRs) and especially for lead fast reactors due to the high boiling point of lead (~1700°C). Instead, postulated LMR accidents can be the result of a wider range of initiating events, which cause an imbalance between heat production and removal.

To facilitate LMR licensing, it is expected that a realistic, scenario-dependent mechanistic source term assessment will be needed.

The SAS4A code (as part of the SAS4A/SASSYS-1 safety analysis code system) was developed by Argonne National Laboratory (ANL) to perform deterministic analysis of design basis and beyond design basis events in sodium fast reactors. Detailed, mechanistic models of thermal, hydraulic, neutronic, and mechanical phenomena are employed to describe the response of the reactor core caused by loss of coolant flow, loss of heat rejection, or reactivity insertion. Accident consequences are modeled, including fuel and coolant heating, fuel and cladding mechanical behavior, and core reactivity feedbacks. The main objectives of SAS4A are to model transient accident conditions and predict key reactor parameters such as reactivity, fuel and cladding temperatures, and cladding strain. SAS4A can also assess fuel failures, including failure modes, failure location and timing, in-pin and ex-pin fuel motion with their implications on core reactivity, and assessment of fuel damage propagation.

The FATE code was developed by Fauske & Associates, LLC, for facility and process modeling and simulation. FATE can model heat and mass transfer, fluid flow, and aerosol behavior in a nuclear fuel cycle or chemical processing facility. FATE’s primary phenomenological capabilities include a generalized multiple-compartment model and network flow model. A variety of chemical species can be modeled in FATE in condensed or vapor form, using thermophysical property correlations from the industry-standard DIPPR 801 database. This allows FATE to model a number of different coolants including water, liquid metals, and gases, as well as fission products as generic chemical species in gas, liquid, or aerosol form.

For this project ANL will work with Fauske & Associates, LLC to couple the SAS4A safety analysis code with the FATE facility modeling code and extend SAS4A to accommodate the use of lead as a reactor coolant. The SAS4A code will be used to model system transients and fuel failures. Its results will be linked to the FATE code to predict radionuclide transport through the primary coolant, cover gas, containment system, and finally release to the environment. The integrated code package will offer a state-of-the-art radionuclide tracking capability for a spectrum of accident scenarios consistent with the plant dynamic response including the reactivity feedback to support Level 2 and 3 probabilistic risk assessments for LMRs. The project will identify areas where further modeling is needed to ensure the combined SAS4A-FATE code can be used as a comprehensive LMR mechanistic source term assessment tool, which will provide a clear development path for the future.