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Quantitative Evaluation of the Post Disassembly Energetics of a Hypothetical Core Disruptive Accident in a Sodium Cooled Fast Reactor

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The analyses of Hypothetical Core Disruptive Accidents (HCDAs) play a fundamental role in the safety assessment of Sodium Fast Reactors (SFRs). The accident sequence is subdivided into different phases suggested by dominant key phenomena. The Initiation Phase (IP) describes the fatal deviation from nominal operation until the failure of single sub-assemblies (SAs), while the subsequent Transition Phase (TP) considers possible damage propagation up to the formation of a large fuel/steel pool. During the TP, a coherent movement of the liquid pool may result in a more compact fuel arrangement leading to recriticality events with consequent upward discharge of the pressurized hot fuel/steel mixture. The power peaks are considered as starting points for the Post-Disassembly Expansion Phase (PDE). The sodium vapor rapidly produced by Fuel-Coolant Interaction (FCI) in the upper plenum displaces and accelerates the surrounding liquid sodium. As a result, a significant mechanical energy may be released acting as a load on structures /vessel. The identification and evaluation of the main phenomena and event paths enhancing or mitigating the mechanical work potential during the PDE is essential to give evidence on the vessel/structures integrity with important design clues for the development of future SFRs. The present paper deals with PDE phenomenology and includes an overview of the quantitative evaluation of the work potential during the PDE of an Unprotected Loss of Flow (ULOF) on the basis of mechanistic SIMMER simulations. For assessing the important determining factors a large number of parametric analyses have been conducted at KIT for an SFR model case and, additionally, KIT simulations performed in previous years have been studied. A wide range of initial conditions and modelling options that may strongly impact the mechanical work potential has been investigated and are integrated in this work, i.e. different liquid fuel mass and temperature conditions, different steel contents in the melt pool, different structure conditions affecting the melt discharge into the sodium plenum, and different driving vapor pressures. The large amount of results has been also employed in the framework of the application of the Phenomenological Relationship Diagram (PRD) to perform a probabilistic evaluation of the work potential of an ULOF/PDE in a sodium small- to medium-sized reactor (SMR, 300 MWe). The present study has been conducted under the research contract between the KIT and the Regulatory Standard and Research Department of National Regulation Authority in Japan.

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