Application of the Severe Accident Code ATHLET-CD. Coolant injection to primary circuit of a PWR by mobile pump system in case of SBLOCA severe accident scenario

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The improvement of the safety of nuclear power plants is a continuously on-going process. The analysis of transients and accidents is an important research topic, which significantly contributes to safety enhancements of existing power plants. In case of an accident with multiple failures of safety systems, core uncovery and heat-up can occur. In order to prevent the accident to turn into a severe one or to mitigate the consequences of severe accidents, different accident management measures can be applied. By means of numerical analyses performed with the compute code ATHLET-CD,[1] the effectiveness of coolant injection with a mobile pump system into the primary circuit of a PWR was studied. According to the analyses, such a system can stop the melt progression if it is activated prior to 10 % of total core is molten.

Within the framework of the joint research project „Weiterentwicklung und Anwendung von Severe Accident Codes – Bewertung und Optimierung von Störfallmaßnahmen" (WASA-BOSS) of the Federal Ministry of Education and Research, HZDR focused on analyses of hypothetical severe accidents for a generic pressurized water reactors of German type KONVOI, assessment and optimization of accident management measures (AMM). Two basic accident scenarios were investigated: station blackout (total loss of AC power supply) and small-break loss-of-coolant accidents (SBLOCA). Results of a SBLOCA are presented here.

NUMERICAL ANALYSES. The ATHLET-CD model developed for a generic KONVOI was used to investigate an accident scenario with a 50 cm^2 leak located in the cold leg of the connected to the pressurizer loop.[2, 3] The accident progression strongly depends on the available emergency core cooling systems (ECCS) and on secondary side systems/procedures like cool-down procedure.[3]
A scenario without secondary cool-down and failure of the sump injection after depletion of the flooding pools leads to a core degradation scenario. With no further water injection from any of the active and passive safety systems – hot leg hydro-accumulators (HAs) are depleted and cold leg HAs are disconnected from the primary circuit – the core outlet temperature $T_{core,out}$ exceeds 400 °C approximately 3 h after beginning of the accident. The reconnection of cold leg HAs and delayed usage of their coolant inventory was also studied,[4] but here this measure is assumed to be unavailable. Secondary side pressure is higher than on primary side with the consequence of reversed heat flux. Therefore, the decay heat is only removed by steam discharge through the leak and consequently the reactor pressure vessel (RPV) level decreases. Melting of absorber material occurs at 3 h 20 min, followed by melting of fuel, release of fission products and relocation to the lower head (LH) until 3 h 45 min. Failure of RPV by creep rupture is predicted at 7 h 30 min (Fig. 1).
As additional AMM, the injection by mobile equipment to the primary circuit was investigated. A connection of the pump to the ECCS injection lines is assumed and a realistic pump characteristic of a mobile fire pump is implemented (nominal pump head 16.5 bar, max. mass flow rate 39 kg/s). A parameter study with variation of the pump activation was performed, covering the range from early activation at

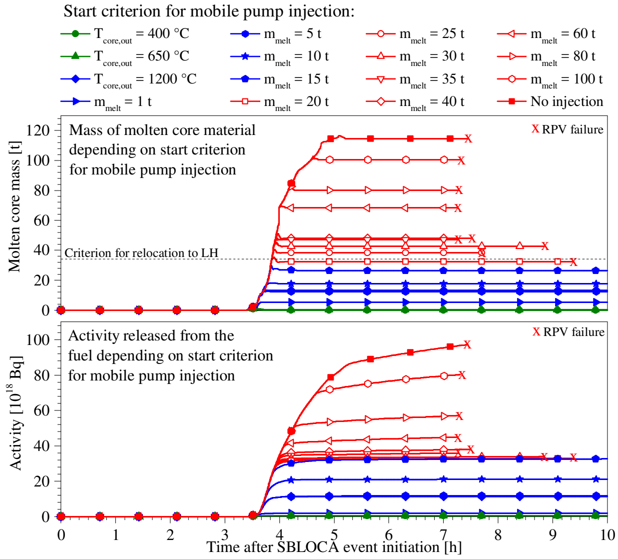

Fig. 1: 50 cm^2-SBLOCA scenario with injection by mobile pump to primary circuit. Mass of molten core material and released activity until failure of RPV.

$T_{core,out}$ = 400 °C to late activation with already partly molten core (caused e.g. by additional delay in preparation of the mobile system). The code simulations showed that for all scenarios with pump injection the further progression of fuel melting could be stopped, and the earlier the pump was activated the lower was the amount of released fission products (FPs, Fig. 1). However, the relocation to the lower plenum and subsequent RPV failure can only be avoided if the mobile pump is activated at a maximum of 15 tons melt mass (approx. 10 % of the core at 3 h 45 min into the transient). The application of the mobile pump system as the only AMM is not sufficient to prevent the release of FPs, despite it is started early in the transient at $T_{core,out}$ = 400 °C (release of 4.4×10^{17} Bq into reactor cooling system is predicted). Additional simulations showed that the application of primary side depressurization performed at $T_{core,out}$ = 400 °C in combination with the mobile pump can prevent the release of FPs.[4]

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