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An Object-Oriented Modelica Model of the Water Level Swell during Depressurization of the Reactor Pressure Vessel of the Boiling Water Reactor

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Abstract : Prediction of the two-phase water mixture level during fast depressurization of the Reactor Pressure Vessel (RPV) resulting from an accident scenario is an important issue from the view point of the reactor safety. Since the level swell may influence the behavior of some passive safety systems, it has been recognized that an assumption which at the beginning may be considered as a conservative one, not necessary leads to a conservative result. This paper discusses outcomes obtained during simulations of the water dynamics and heat transfer during sudden depressurization of a vessel filled up to a certain level with liquid water under saturation conditions and with the rest of the vessel occupied by saturated steam. In case of the pressure decrease e.g. due to the main steam line break, the liquid water evaporates abruptly, being a reason thereby, of strong transients in the vessel. These transients and the sudden emergence of void in the region occupied at the beginning by liquid, cause elevation of the two-phase mixture. In this work, several models calculating the water collapse and swell levels are presented and validated against experimental data. Each of the models uses different approach to calculate void fraction. The object-oriented models were developed with the Modelica modelling language and the OpenModelica environment. The models represent the RPV of the Integral Test Facility Karlstein (INKA) – a dedicated test rig for simulation of KERENA – a new Boiling Water Reactor design of Framatome. The models are based on dynamic mass and energy equations. They are divided into several dynamic volumes in each of which, the fluid may be single-phase liquid, steam or a two-phase mixture. The heat transfer between the wall of the vessel and the fluid is taken into account. Additional heat flow rate may be applied to the first volume of the vessel in order to simulate the decay heat of the reactor core in a similar manner as it is simulated at INKA. The comparison of the simulations results against the reference data shows a good agreement.

Keywords : boiling water reactor, level swell, Modelica, RPV depressurization, thermal-hydraulics
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