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Mass Transfer Simulation Model for Justification Sodium Purification System Characteristics

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Provision of the safe and reliable operation of Nuclear Power Plant with sodium fast reactor requires maintaining of the quality of the sodium coolant in regards of oxygen and hydrogen contents at the specific level, since even a few parts per million of sodium oxide can have a deleterious effect on the performance and reliability of a fast reactor cooled by sodium and its heat transfer system.

The main component of sodium coolant purification system is a cold trap. In a cold trap the sodium is cooled and impurities present in amounts exceeding those which will dissolve at the lower temperature precipitate. Cold traps are designed to promote controlled precipitation and to retain the precipitate in the trap.

Justification of cold trap operational parameters at the existing sodium fast reactors was performed 30-40 years ago based on experiments and semi-empirical calculations. Today's simulation technologies can be used to perform detailed computer analysis of cold trap performance taking in account accumulated experimental experience. But due to complexity of the heat and mass transfer processes effecting on each other and occurring in the cold trap simultaneously, there is a need to upgrade and validate standard calculation models incorporated in the existing codes.
The method of consecutive heat and masstransfer simulation using custom OpenFOAM solver to determine the retain coefficient of the cold trap mock-up is discussed in this work. The new solver has been developed, which calculates fields of dissolved oxygen and suspended sodium oxide particles and the rate of their accumulation in the cold trap as well.

Calculations were performed in two steps: first, using standard thermal-hydraulic OpenFOAM solver and modified scalartTransportFoam solver at the second step, setting results of the first step of simulation as initial conditions.

Formation of particulate in the cold trap volume was accounted by introducing the oversaturation mechanism in to the solver. Saturation concentration usually defined as temperature function, which derived from experiment data approximation. Temperature dependence of the diffusion coefficient was incorporated in the solver source code in order to get more accurate results.

In the result of performed simulations the distributions of velocity, pressure, temperature and concentration of both dissolved and particulate phases inside the cold trap were obtained as well as the rate of impurity accumulation. It has been demonstrated that suggested methodology allows one to analyze operational parameters of a purification systems of sodium facilities.

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