Abstract

Energy production by nuclear fusion has been an important research topic for over fifty years. For now, the fusion reaction of deuterium with tritium is considered to be the most viable option. However, because of the scarcity of tritium, a method to produce it within the fusion reactor had to be devised. This was embodied in the idea of a tritium breeding blanket. In most blanket concepts, liquid PbLi is flowing in the reactor's walls and by the interaction of fusion neutrons with lithium, tritium is produced within this liquid metal. A remaining issue here is to extract the produced tritium from the liquid PbLi so it can be reinjected in the fusion plasma. All proposed methods aiming to do this have fallen short so far. Recently however, a new promising technology emerged, called the vacuum sieve tray (VST) which is based on the tritium extraction from small PbLi droplets falling in a vacuum tank. The new highlight which makes this method so attractive is that the oscillation of the droplets, put in motion by the detachment from the injected jet, enhances the tritium extraction by one order of magnitude compared to non-oscillating droplets.

The Tritium Laboratory of Karlsruhe (TLK) aims to experimentally validate this method within the next years. The specific aim of this Master's thesis was to design, simulate and optimise the core of the experimental set-up (where the actual extraction takes place). The simulation allowed gaining more insight in the physical principles governing the characteristics of the experiment. Based on the outcome, the experimental set-up consisting principally of an upper tank (for the dissolution of tritium in the PbLi) and a lower tank (for the extraction of tritium), was optimised. In this process, both safety and performance arguments were taken into account. Also, the time variation of all parameters along the experiment was minimised in order to make the experimental results more reliable. Finally, several experimental campaigns were devised aiming mainly to verify the correctness of the equation used for the calculation of the extraction efficiency and to optimally fit the results to this equation. This way a complete mathematical model is developed which can be used to upscale the VST theory to the PbLi mass flows occurring in the different breeding blanket concepts.

If the theory proves to be correct, the designed experimental set-up will be able to reach extraction efficiencies as high as 99 %. This would mean an important breakthrough for the tritium extraction systems (TES). The results of this thesis allow to optimally investigate the feasibility of the vacuum sieve tray concept with a reasonably sized experiment and in relevant conditions using tritium. The outcome will be used in the fabrication of the experimental rig that will be installed at TLK.