Experimental Study of Buoyant Plume and Thermal Stratification in a Liquid Metal Nuclear Reactor

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Abstract

The development of new generation liquid metal cooled reactors leads to numerous advantages in the nuclear energy technology, such as a higher power density and improved operating safety.The Belgian nuclear research institute (SCK¢CEN) is developing MYRRHA, a subcritical liquid metal cooled reactor and commissioned at VKI the construction of a scaled water model.

One of the aspects to be tested is the formation of a stratified buoyant plume establishing during the reactor shutdown in the above core region that may influence the heat removal in natural convection working conditions and affect the integrity of the system. The thermal stratification of the plume anticipated in such a transient and the magnitude of the upper plenum thermal gradient should be assessed as a function of the core decay power.

The experimental techniques proposed for the analysis of the transient are the Particle Image Velocimetry and the Laser Induced Fluorescence: the PIV technique will be used for the measurement of the velocity field, while the thermal field will be measured by LIF.

The use of planar optical techniques for velocity and temperature measurements leads to numerous advantages. They can be used simultaneously, as required by the analysis of transient flows. They can picture complex phenomena like the thermal stratification of a buoyant plume . Furthermore the simultaneous measurements of the velocity and temperature fields allows the establishment of fine correlations between the buoyancy driven convective motion and the heat transfer mechanisms.

Before applying the proposed analysis to the water model of the whole MYRRHA reactor the combined PIV and LIF will be tested in step by step increasing complexity models.

The simultaneous application of PIV and LIF technique will be first assessed for natural convection cases by performing measurements on a vertical square enclosure uniformly heated in one side and uniformly cooled the other side thanks to the use of two Peltier elements. This model is chosen for the large availability of experimental and numerical data in literature. The aim is to determine which are the best seeding conditions for natural convection PIV test in water and the dye concentration that allows the highest temperature resolution obtainable through one color LIF.

A further step is the application of the proposed experimental study on the upper plenum of a small two dimensional natural convection model (Aquarium). The loop is designed in order to respect as much as possible the similarity with the MYRRHA hydraulic circuit working in natural convection conditions. The loop includes a heating section where a buoyancy plume develops and produces a thermal stratification in the upper plenum and a cooling section. The overall effect is a mass flow driven only by natural convection (Thermosyphon loop). The tests on the model will allow to validate the experimental techniques chosen and confirm the adequacy of their application for the analysis of stratification in the large scale model. Moreover they will allow to achieve a better understanding of the parameters that could influence the thermal stratification in the upper vessel region, such as the upper plenum geometry, the presence of obstacles in the above heat source region and the power distribution in the heat source.
