Couplings and instabilities in reactor systems

INSTAB

Research group
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Introduction

Development of thermal stratification in the suppression pool of a BWR is of safety concern since it reduces the steam condensation capacity of the pool, increases the pool surface temperature, and thus leads to higher containment pressures. There is a need for validated tools for simulation of realistic accident scenarios with interplay between phenomena, safety systems, operational procedures, and overall containment performance. The INSTAB project has increased understanding of the phenomena related to BWR pressure suppression function and has enhanced capabilities to analyze Nordic BWR containments under transient and accident conditions.

Mixing and erosion of thermal stratification

Sparger tests on mixing and behavior of a thermocline have been carried out in the PPOOLEX facility in 2015-2018.

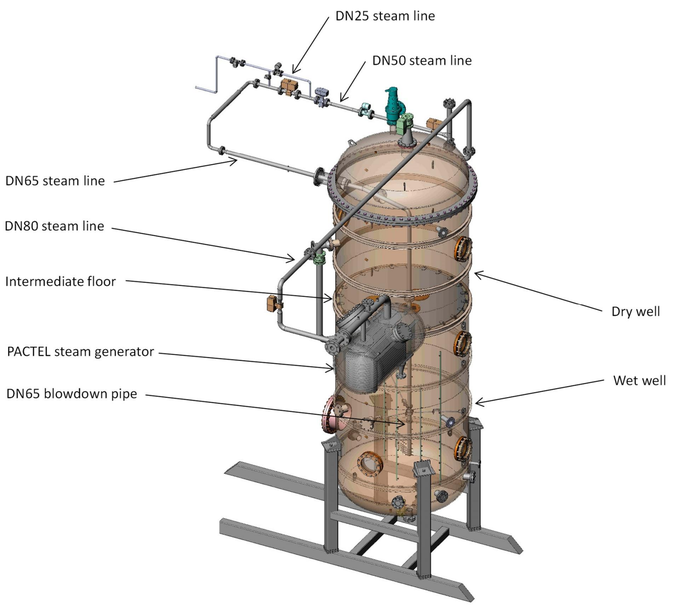
Findings:

Complete mixing through internal circulation of the pool can be achieved, if the flow mode is suitable.

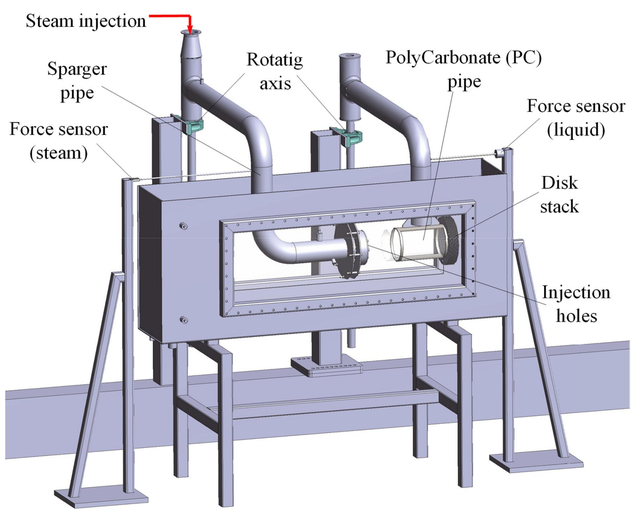
Complete mixing through an erosion process can be achieved with quite a small steam flow rate.

In some situations a new stratification process seems to start although the steam mass flow rate is kept constant.

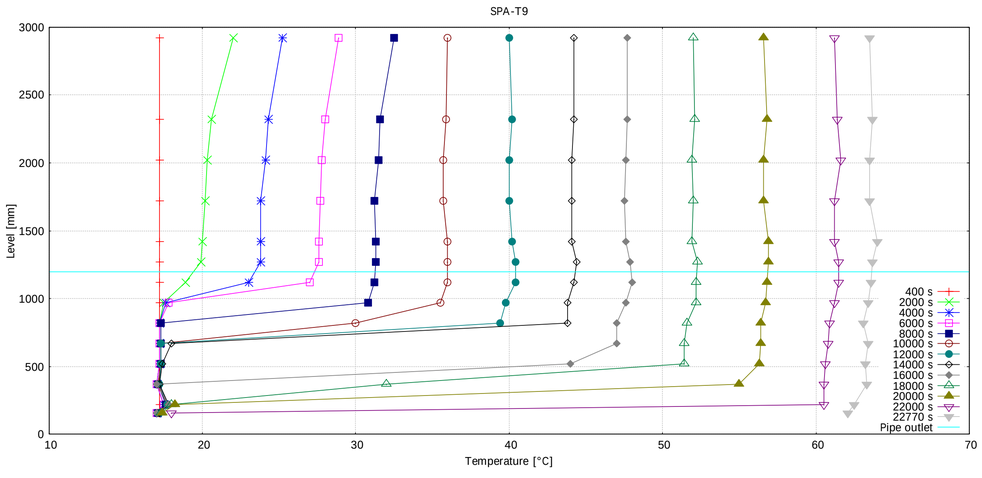
Mixing of a thermally stratified pool with the help of spray injection from above is possible.



PPOOLEX test facility.



SEF-POOL test facility.



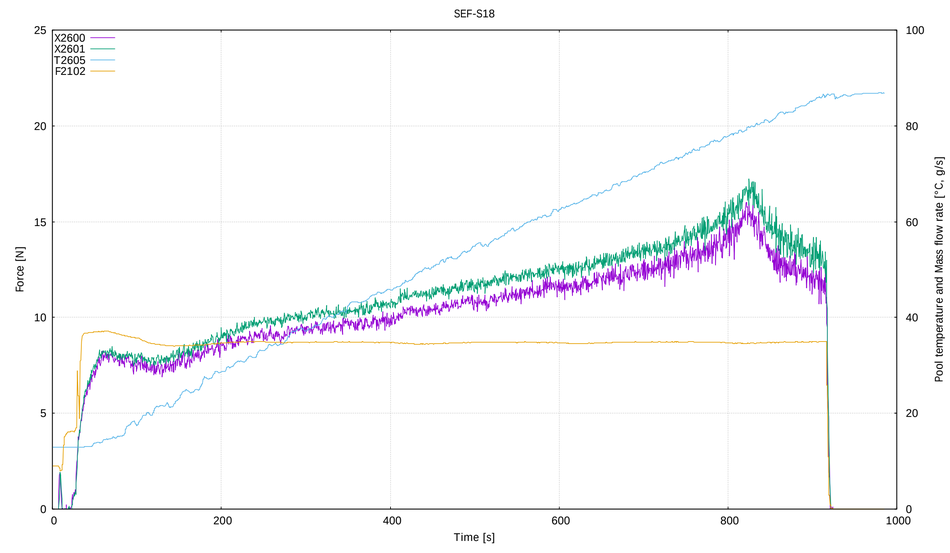
Development of vertical temperature profile in a PPOOLEX sparger test.

Separate effect tests

An extensive test series has been run in the SEF-POOL facility. Data of the characteristics of small-scale phenomena affecting effective momentum sources in the oscillatory bubble regime has been gathered. This data supports the validation effort of the DCC and interfacial area models of CFD codes for steam injection through spargers at VTT and LUT.

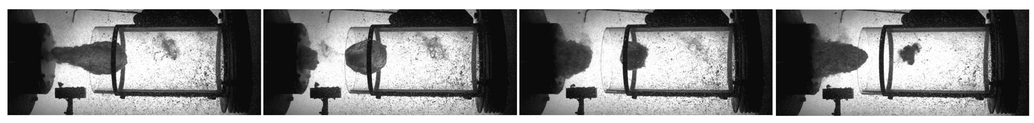
Findings:

All sub-sonic regimes present a strong dependency of measured forces with the sub-cooling.



Measured forces in a SEF-POOL test.

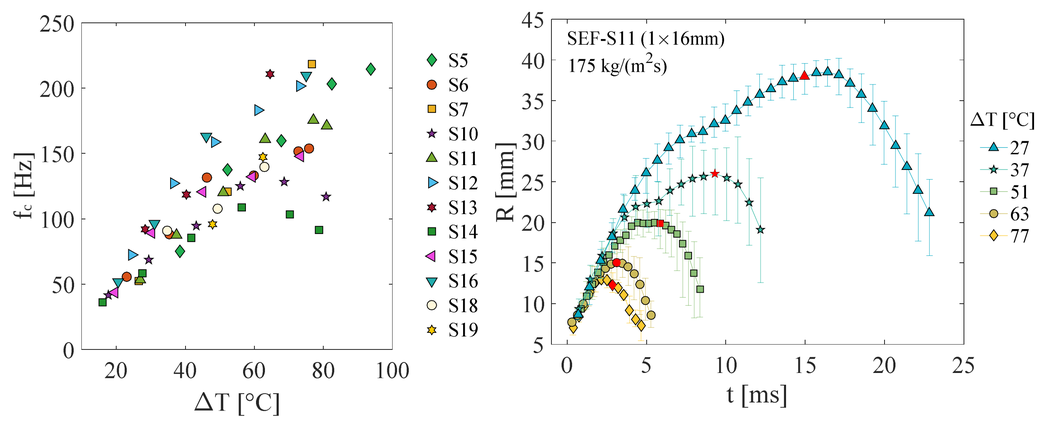
Qualitative analysis of video images show that the oscillatory motion of the steam bubbles can be divided into three parts: (i) the bubble begins to grow attached to the injection holes, (ii) detaches when the force balance becomes positive in the direction of the steam injection, (iii) collapses as the neck connecting the bubble to the injection hole reduces the steam flow into the bubble.



Collapsing steam bubbles (Q=174 kg/m^{2}s, T=85 °C, d=16 mm, Δt=4285,68 µs).

Simplified simulation models

The simplified effective heat source (EHS) and effective momentum source (EMS) models for simulation of steam injection into a pool filled with sub-cooled water, proposed by KTH, reduce the needed computational capacity. The models can be used in any thermal-hydraulic code. Extensive validation effort against the PPOOLEX and SEF-POOL tests is under way.



Bubble collapsing frequencies and bubble radius as a function of sub-cooling.

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