Title	Modeling of Condensation, Stratification, and Mixing Phenomena in a Pool of Water
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ISBN	978-87-7893-295-2
Date	December 2010
Project	NKS-R / POOL
No. of pages	90
No. of tables	4
No. of illustrations	73
No. of references	57

Abstract

This work pertains to the research program on Containment Thermal-Hydraulics at KTH. The objective is to evaluate and improve performance of methods, which are used to analyze thermal-hydraulics of steam suppression pools in a BWR plant under different abnormal transient and accident conditions. As a passive safety system, the function of steam pressure suppression pools is paramount to the containment performance. In the present work, the focus is on apparently-benign but intricate and potentially risk-significant scenarios in which thermal stratification could significantly impede the pool's pressure suppression capacity. For the case of small flow rates of steam influx, the steam condenses rapidly in the pool and the hot condensate rises in a narrow plume above the steam injection plane and spreads into a thin layer at the pool's free surface. When the steam flow rate increases significantly, momentum introduced by the steam injection and/or periodic expansion and shrink of large steam bubbles due to direct contact condensation can cause breakdown of the stratified layers and lead to mixing of the pool water. Accurate prediction of the pool thermal-hydraulics in such scenarios presents a computational challenge. Lumped-parameter models have no capability to predict temperature distribution of water pool during thermal stratification development. While high-order-accurate CFD (RANS, LES) methods are not practical due to excessive computing power needed to calculate 3D high-Rayleigh-number natural circulation flow in long transients. In the present work, a middle-ground approach is used, namely CFD-like model of the general purpose thermal-hydraulic code GOTHIC. Each cell of 3D GOTHIC grid uses lumped parameter volume type closures for modeling of various heat and mass transfer processes at subgrid scale. We use GOTHIC to simulate POOLEX/PPOOLEX experiment, in order to (a) quantify errors due to GOTHIC's physical models and numerical schemes, and (b) propose necessary improvements in GOTHIC sub-grid scale modeling. The study performed on thermal stratification in a water pool indicates that GOTHIC CFD-like model is fit for reactor applications in complex fluid-physics scenarios that avoids both over-simplification (as in single lumped-parameter model) and over-complication (as in CFD models). However, simulation of direct steam injection into a subcooled pool cannot be predicted reliably with the existing models. Thus we develop "effective heat source" and "effective momentum" approaches, and provide feasibility study for the prediction of thermal stratification and mixing in a BWR pressure suppression pool. The results are encouraging and further activity on the development and implementation of the proposed models in GOTHIC is currently underway.

Key words: BWR pressure suppression pool, thermal stratification, mixing, effective models, GOTHIC