http://dx.doi.org/10.5516/NET.02.2013.523

ASSESSMENT OF CONDENSATION HEAT TRANSFER MODEL TO EVALUATE PERFORMANCE OF THE PASSIVE AUXILIARY FEEDWATER SYSTEM

YUN-JE CHO, SEOK KIM, BYOUNG-UHN BAE, YUSUN PARK, KYOUNG-HO KANG, and BYONG-JO YUN[a*]
Thermal Hydraulics Safety Research Department, Korea Atomic Energy Research Institute
1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
[*]Corresponding author. E-mail : bjyun@pusan.ac.kr

Invited September 12, 2013
Received October 07, 2013
Accepted for Publication October 14, 2013

As passive safety features for nuclear power plants receive increasing attention, various studies have been conducted to develop safety systems for 3rd-generation (GEN-III) nuclear power plants that are driven by passive systems. The Passive Auxiliary Feedwater System (PAFS) is one of several passive safety systems being designed for the Advanced Power Reactor Plus (APR+), and extensive studies are being conducted to complete its design and to verify its feasibility. Because the PAFS removes decay heat from the reactor core under transient and accident conditions, it is necessary to evaluate the heat removal capability of the PAFS under hypothetical accident conditions. The heat removal capability of the PAFS is strongly dependent on the heat transfer at the condensate tube in Passive Condensation Heat Exchanger (PCHX). To evaluate the model of heat transfer coefficient for condensation, the Multi-dimensional Analysis of Reactor Safety (MARS) code is used to simulate the experimental results from PAFS Condensing Heat Removal Assessment Loop (PASCAL). The Shah model, a default model for condensation heat transfer coefficient in the MARS code, under-predicts the experimental data from the PASCAL. To improve the calculation result, The Thome model and the new version of the Shah model are implemented and compared with the experimental data.

KEYWORDS : Passive Safety System, PAFS, Condensation Heat Transfer, MARS

1. INTRODUCTION

After the Fukushima accident, an increasing interest has been raised in passive safety systems that effectively cools down the reactor core even in the case when entire on-site and off-site powers are unavailable due to unexpected causes such as natural disasters. The Passive Auxiliary Feedwater System (PAFS) is one of the advanced safety features under development for an Advanced Power Reactor Plus (APR+) in South Korea. Because the PAFS removes decay heat from the reactor core under transient and accident conditions, it is important to properly evaluate the heat capability of PAFS under the postulated accident conditions [1]. With the aim of validating the cooling performance of the PAFS, the experimental program of the separate effect test and integral effect test were carried out at the Korea Atomic Energy Research Institute (KAERI) [2]. As an experimental program, the PAFS Condensing heat removal Assessment Loop (PASCAL) test facility was constructed to investigate the condensation heat transfer and natural convection phenomena in the PAFS [3].

In addition to the experimental research, it is important to use a safety analysis code because it is required to simulate various postulated accidents that cannot be done by experiments. Thus, the assessment for the calculation performance of the safety analysis code was also performed using the Multi-dimensional Analysis of Reactor Safety (MARS) code developed at KAERI [4]. A comparison of the calculation results against the experimental data found that the model of the condensation heat transfer in the MARS code underestimated the condensation heat transfer at the inner surfaces of the condensation heat exchanger in the PAFS.

Therefore, in this paper, existing models for condensation heat transfer inside a pipe were assessed by implementing the models into the MARS code and comparing the MARS calculation result with the PASCAL experi-

[a] Present affiliation: School of Mechanical Engineering, Pusan National University, Busandaehak-ro 63beon-gil, Geumjeong-gu, Busan, 609-735, Korea

mental data. The condensation models used for the assessment were the Shah model [5], Thome model [6], and modified Shah model [7]. Through assessment of the results, the development direction for the proper model to simulate the condensation heat transfer in the PAFS was suggested.

2. PASCAL TEST FACILITY

2.1 Characteristics of PAFS

The PAFS is designed to be separately installed in each secondary side of APR+ instead of a conventional active auxiliary feedwater system. The steam from a steam generator (SG) flows into the passive condensation heat exchanger (PCHX) submerged in a passive condensate cooling tank (PCCT) and the condensate goes into the steam generator through the economizer nozzle. The schematics of PAFS in a single loop is shown in Fig. 1.

The PAFS removes decay heat using natural circulation through a PCHX, which consists of 4 tube bundles. One tube bundle has 60 horizontal condensate tubes [8]. The condensate tube has 3 degree of inclination to prevent a water hammer effect as shown in Fig. 2.

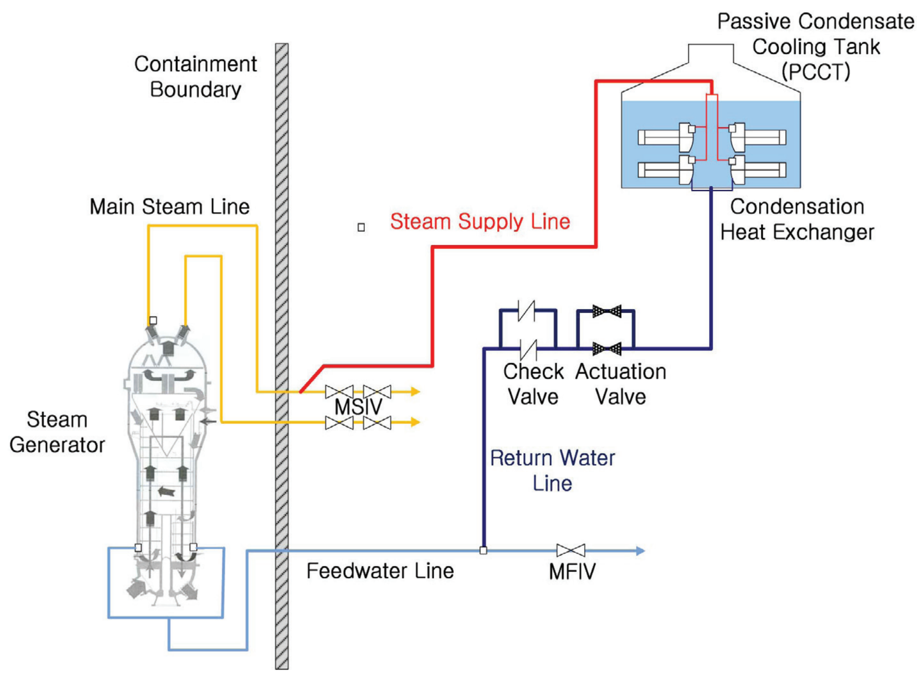

Fig. 1. Conceptual Diagram of the PAFS

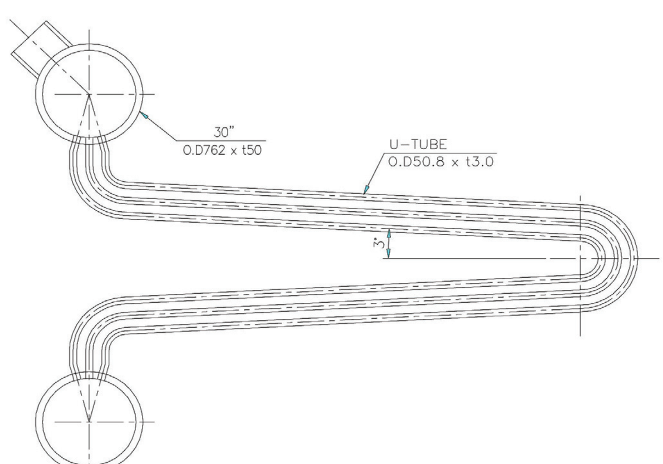

Fig. 2. Design of Condensation Tube