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Experimental study of turbulent jet induced by steam jet condensation through a hole in a water tank ☆

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Abstract

A turbulent jet induced by steam jet condensation in a water pool was investigated experimentally. An experimental apparatus equipped with a steam boiler, a single-hole steam sparger, and a water pool, etc. was used. For the measurements, a pitot tube and thermocouples were used for turbulent flow velocity and temperatures, respectively. Overall flow shapes of the turbulent jet by the steam jet condensation are similar to those of axially symmetric turbulent jet flows. The angular coefficients of turbulent rays are quantitatively comparable between the traditional turbulent jet flows and the turbulent jet flows induced by the steam jet condensation in this work. Although the turbulent flows were induced by the steam jet condensation, general theory of turbulent jets was found to be applicable to the turbulent flows of this work.

Keywords: Steam condensation; Steam jet; Turbulent jet

1. Introduction

In the design of the APR1400 (Advanced Pressurized water Reactor 1400MWe), the IRWST (In-containment Refueling Water Storage Tank) equipped with spargers, through which steam and/or water at high temperature and pressure is blown down into water in the tank, is provided to depressurize the reactor in certain events. When hot steam and/or water is ejected into relatively cold water pool, most of the steam and/or water is condensed in the pool and in the result the water temperature will increase. In a large water pool, pool thermal mixing is dependent upon the momentum introduced by steam/water ejection and condensation, overall temperature distribution in the pool, and geometrical conditions of the pool, etc. In the design of such a large pool, the prediction of the thermal mixing using a computer code with the capability of multi-dimensional thermal–hydraulic analysis is requisite in a practical sense. Before adoption of the computer code analysis to the real design case, some verification and validation calculations are necessary to confirm its applicability to an interest aspect. An experimental result on a single steam jet condensation, for example, will provide such validation data for a multi-dimensional thermal–hydraulic computer code.

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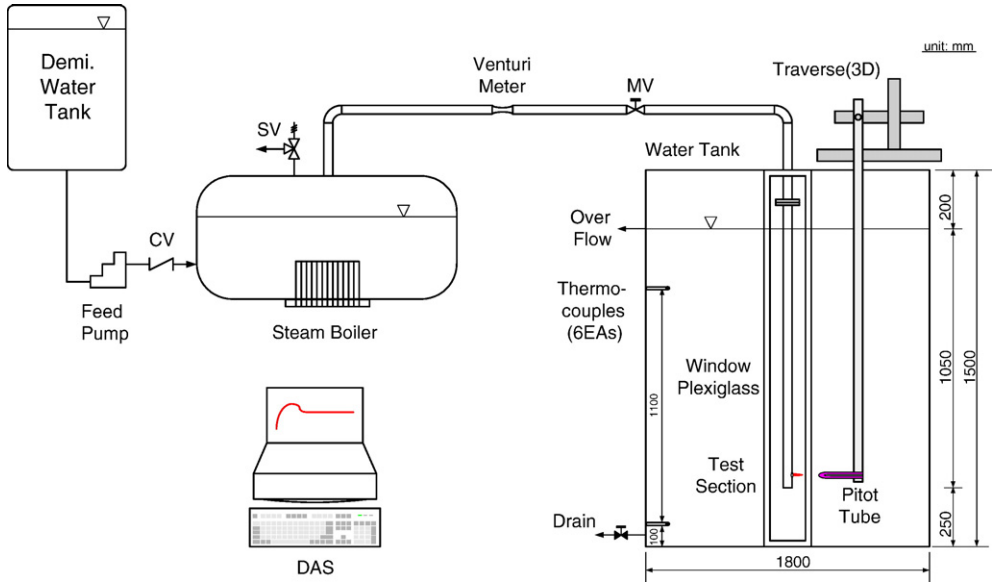

Fig. 1. Schematic diagram of the experimental apparatus.

Many works on steam jet condensation through single hole or nozzle in a water tank have been conducted. Those studies focused on steam jet characteristics especially on condensation oscillation [1–7], condensation jet shape [8–11], condensation jet length [12,13], and heat transfer characteristics of steam jet condensation [14–16]. And some of studies tried to understand the turbulent jet flow induced by steam jet condensation experimentally and/or theoretically, but their efforts were confined in restricted aspects, e.g. overall turbulent jet angle using dye, jet velocity distribution, jet temperature distribution, etc. In these circumstances, multi-dimensional CFD (Computational Fluid Dynamics) analysis appears to be one of strong candidates to analyze thermal mixing phenomena in a large water pool such as IRWST in APR1400 design, in which high pressure and temperature steam and/or water is discharged into the water pool through multi-hole sparger. In this aspect, the understanding of the turbulent jet flow induced by steam jet

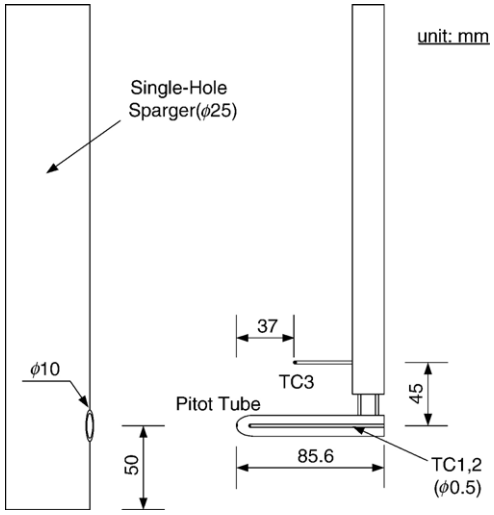

Fig. 2. Single-hole sparger and pitot tube/thermocouples.