

## Research Article

# Opposing Mixed Convection Heat Transfer for Turbulent Single-Phase Flows

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Convection, wherein forced and natural convections are prominent, is known as mixed convection. Specifically, when a forced convection flow is downward, this flow is called opposing flow. The objectives of this study are to gain a comprehensive understanding of opposing flow mixed convection heat transfer and to establish the prediction methodology by evaluating existing correlations and models. Several heat transfer correlations have been reported related to single-phase opposing flow; however, these correlations are based on experiments conducted in various channel geometries, working fluids, and thermal flow parameter ranges. Because the definition of nondimensional parameters and their validated range confirmed by experiments differ for each correlation reported in previous studies, establishing a guideline for deciding which correlation should be selected based on its range of applicability and extrapolation performance is important. This study reviewed the existing heat transfer correlations for turbulent opposing flow mixed convection and the single-phase heat transfer correlations implemented in the thermal-hydraulic system codes. Furthermore, the authors evaluated the predictive performance of each correlation by comparing them with the experimental data obtained under various experimental conditions. The Jackson and Fewster, Churchill, and Swanson and Canton correlations can accurately predict all the experimental data. The effect of the difference in the thermal boundary conditions, i.e., uniform heat flux and uniform wall temperature, on the turbulent mixed convection heat transfer coefficient is not substantial. The authors confirmed that heat transfer correlations using the hydraulic-equivalent diameter as a characteristic length can be used for predictions regardless of channel-geometry differences. Furthermore, correlations described based on nondimensional dominant parameters can be used for predictions regardless of the differences in working fluids. The authors investigated the extrapolation performance of the mixed convection heat transfer correlations for a wide range of nondimensional parameters and observed that the Jackson and Fewster, Churchill, and Aicher and Martin correlations exhibit excellent extrapolation performance with respect to natural and forced convection flows, indicating that they can be applied beyond the parameter range validated experimentally.

## 1. Introduction

The rapid cooling of a reactor pressure vessel (RPV) wall embrittled owing to exposure to neutrons could propagate cracks, if they exist, in the wall because of induced thermal stresses. This event is called pressurized thermal shock

(PTS) and is one of the most severe loads that could act on a RPV wall. Loss of coolant accident (LOCA) in a pressurized water reactor (PWR) is the most important and commonly studied accident. During a LOCA, when the water inventory of the primary system decreases and water from the emergency core cooling system is supplied to the cold

# Heat Transfer In Turbulent Mixed Convection

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