# Preliminary Experiments on Single-Phase Heat Transfer and Onset of Nucleate Boiling in a Narrow Rectangular Channel for Research Reactors

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## 1. Introduction

The plate-type fuel with narrow rectangular channels is adopted in high-performance research reactors requiring high neutron flux. Thermal-hydraulic phenomena such as single-phase heat transfer, onset of nucleate boiling (ONB), and critical heat flux in these channels differ from those in circular tubes, and are sensitive to geometric parameters including aspect ratio and heater configuration. Since the heat transfer correlation widely used in engineering field, developed by Dittus-Boelter [1] based on circular-tube data, may not accurately predict heat transfer in narrow rectangular channels, a dedicated correlation is required.

To this end, Using a previously established thermal-hydraulic test facility for vertical narrow rectangular channel conditions, preliminary single-phase heat transfer and ONB experiments were conducted. This paper describes the test section, experimental methodology, and results compared against existing correlations.

## 2. Methods and Results

### *2.1 Thermal-Hydraulic Test Loop*

The test facility consists of a primary circulation loop, pressurizer, pre-heater, secondary cooling system, and data acquisition system. The pressurizer maintains system pressure above 5 bar, and the secondary cooling system removes heat via a cooling tower and heat exchanger.

The test section is a both-sided heated narrow rectangular channel with a width of 66.6 mm, gap of 2.35 mm, and heated length of 600 mm, comprising a high-heating section (SUS430, 1.0 mm) and low-heating section (SUS304, 0.2 mm). Since direct-contact thermocouples produce significant errors in electrically heated elements due to the Ettingshausen-Nernst effect, non-contact pyrometers were adopted for wall temperature measurement [2]. Instrumentation includes a Coriolis flow meter, pressure and differential pressure transmitters, thermocouples, and a power meter, with uncertainties quantified through national-standard calibration.

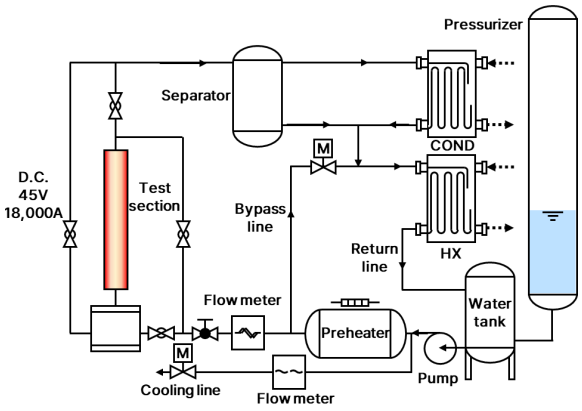


Fig. 1. Schematic of Test Loop

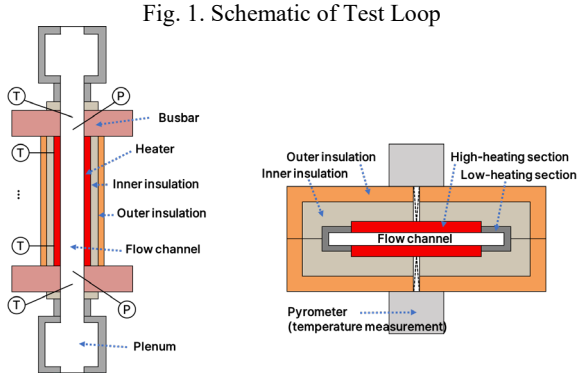


Fig. 2. Schematic of Test Section

### *2.2 Preliminary Single-Phase Heat Transfer Experiments*

Experiments were conducted for 16 conditions under upward flow (inlet velocity 2.0–5.5 m/s, inlet temperature 35 and 50 °C). The heat transfer coefficient was obtained via a quasi-steady-state method with continuously increasing heater power, and the Nusselt number (Nu) was derived from pyrometer-measured wall temperatures at five axial locations.

Results were compared against the Dittus-Boelter and Sieder-Tate [3] correlations and the SE3 and SE4 correlations (CEA) developed under Jules Horowitz Reactor (JHR) conditions [4]. SE3 and SE4, developed for narrow rectangular channels, agreed well with the data, while Dittus-Boelter and Sieder-Tate predicted significantly lower Nu.

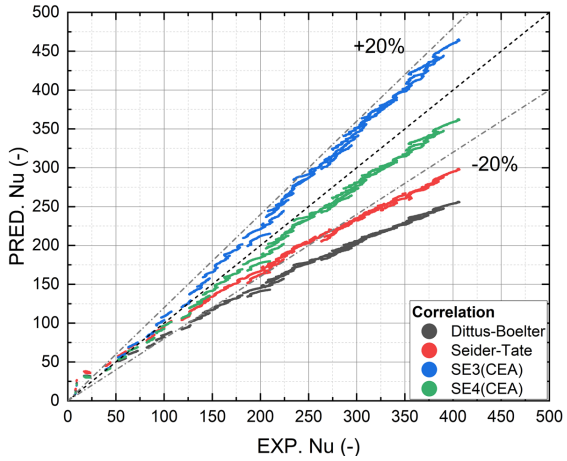


Fig. 3. Single-phase heat transfer results: comparison of measured Nusselt numbers with predictions

### *2.3 Preliminary Onset of Nucleate Boiling (ONB) Experiments*

The ONB experiments extended the single-phase tests by continuously increasing heat flux until nucleate boiling was observed. The ONB criterion of Forrest [5] — a partitioned boiling heat flux ratio of 7.5%, grounded in Bergles-Rohsenow [6] — was adopted. A local single-phase heat transfer coefficient correlation at the channel outlet was separately derived, and ONB conditions were obtained through iterative heat balance computation by using the correlation. The measured ONB heat flux agreed reasonably with the Bergles-Rohsenow correlation.

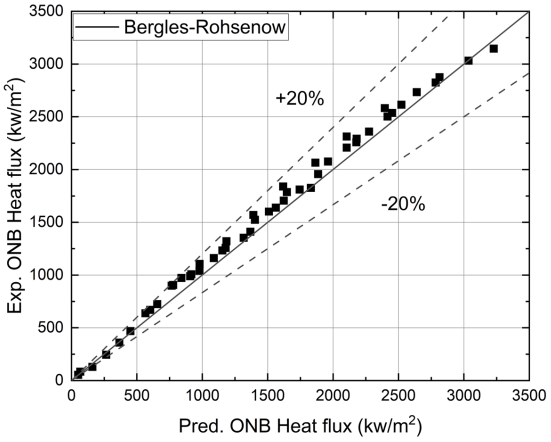


Fig. 4. ONB experimental results: comparison of measured ONB heat flux with predictions

## 3. Conclusions

Preliminary single-phase heat transfer and ONB experiments were performed in a vertical narrow rectangular channel test facility. Non-contact pyrometers eliminated wall temperature measurement errors associated with direct-contact thermocouples [2]. The Dittus-Boelter [1] and Sieder-Tate [3] correlations significantly under-predicted the experimental Nu, while the SE3·SE4 correlations [4] agreed well with the data. The measured ONB heat flux was in reasonable agreement with the Bergles-Rohsenow correlation [6]. Future work will expand the experimental database to quantify thermal margins for high-performance research reactor design.

## ACKNOWLEDGEMENT

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