An experimental setup for investigation of thermal oscillation induced by dryout in printed circuit steam generator

Department of Nuclear & Quantum Engineering

Jin Su Kwon[a], Doh Hyeon Kim[a], Jeong Ik Lee[a,*], Sang Ji Kim[b]

[a]Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, 373-1 Guseong-dong Yuseong-gu,Daejeon 305-701, Republic of Korea

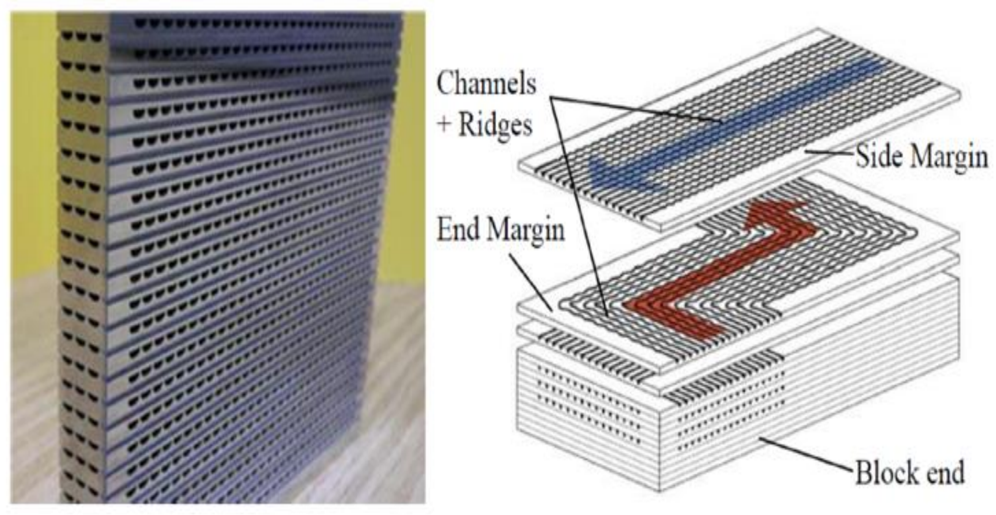
[b]Korea Atomic Energy Research Institute 150 Dukjin-dong, Yuseong-gu, Daejon 305-353, Republic of Korea

*Corresponding author: jeongiklee@kaist.ac.kr

Introduction

▣ Printed circuit steam generators (PCSG) have been studied as a potential candidate for the steam generator in SMR (Small Modular Reactor)

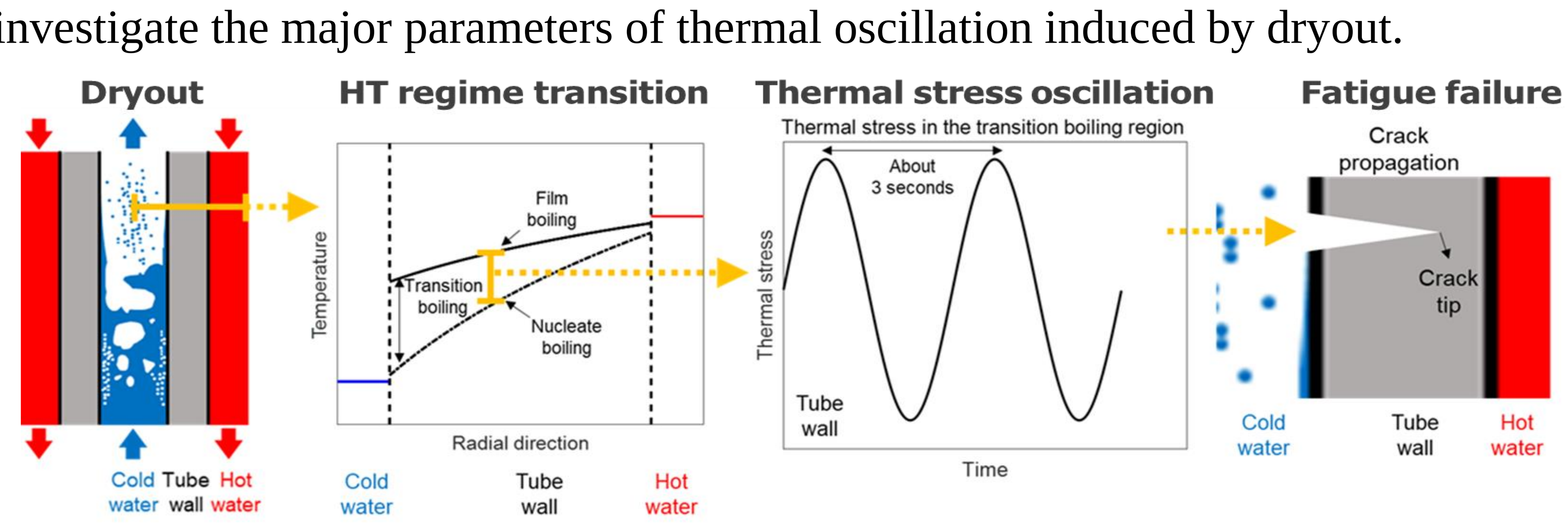
▣ The dryout occurs inside the PCSG inherently since it is used as an once-through type steam generator.



▲ Configurations of PCHE

▣ Dryout front oscillates regardless of changes in mass flow rate. The movement of dryout front induces a transition in boiling regions between nucleate boiling and mist evaporation region, which leads to a significant wall temperature oscillation.

▣ The purpose of this study is to design an experimental facility in order to investigate the major parameters of thermal oscillation induced by dryout.



▲ Mechanism of thermal fatigue induced by dryout oscillation

Setup for the experiments

1. Main loop

▣ The key target of the experimental facility design is having capability as follows: (1) to produce and cool the steam under a few atmospheric pressures, (2) to control the experimental parameters such as heat flux and mass flux at the test section.

▣ Deionized water is used for the working fluid as a simulant of the pressurized water used in the steam generator.

▣ The facility is a flow loop made up of the test section with the heater, inventory tank, cooler, pump, and various instrument devices.

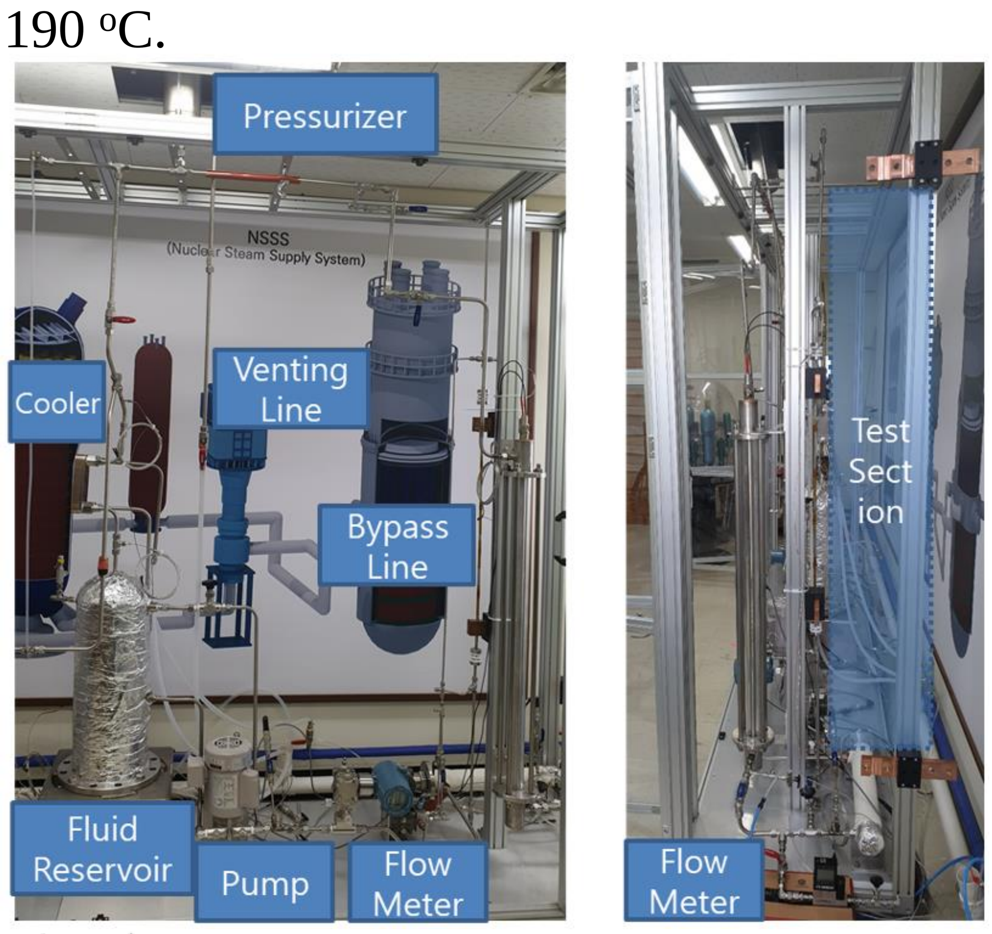
▣ To produce the superheated steam in the flow channel, the rectifier supplies the DC current to the resistance heating section.

▣ For the experimental conditions, inlet temperatures of the test section are fixed to 40 ^{o}C and outlet temperature is up to 190 ^{o}C.

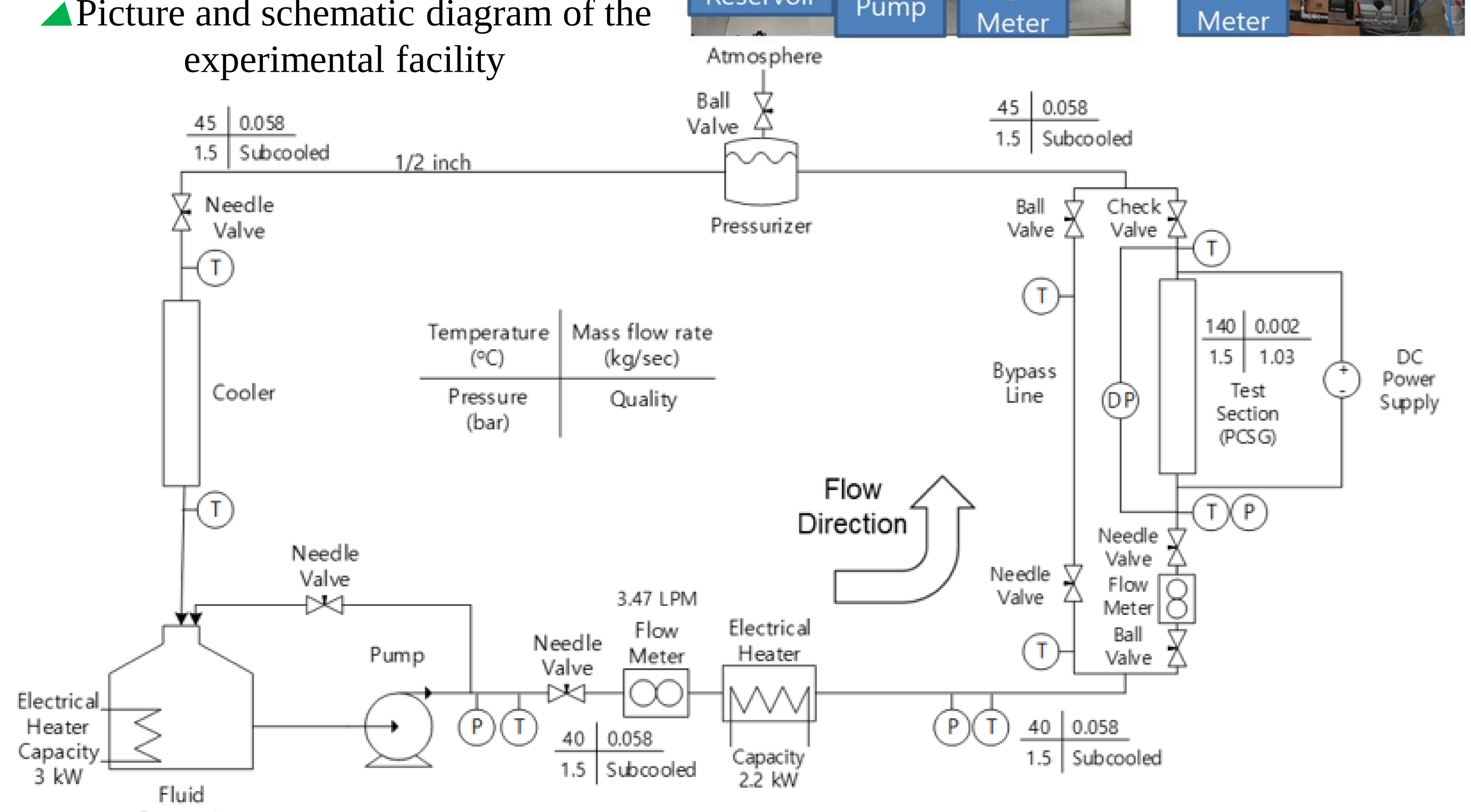
▣ The operating pressure is one to five times of atmospheric pressure.

▣ Moreover, constant flow rate between 1 to 50 ccm injected into the test section is supplied through a flow rate controller

▣ In order to prevent the occurrence of two-phase flow instability caused by the rapid volume expansion, a throttle valve and check valve are placed at the inlet and outlet of the test section.



▲Picture and schematic diagram of the experimental facility



2. Test section

▣ the test section consists of three parts: (1) resistance heating section, (2) visualization window and (3) clamp.

▣ To facilitate the sophisticated measurement of experimental parameters, the test section has only one semi-circular flow channel in the middle.

▣ To produce the superheated steam in the flow channel, the rectifier supplies the DC current to the resistance heating section.

▣ The dimension of the heating section is determined by considering the electrical resistivity and structural stability.

▣ The height is set to 1.5 meters considering the test section buckling and acceptable wall temperatures.

▣ The semi-circular shaped flow channel and diameter of 2 mm are derived from the optimized PCSG geometry. One difference in the test section from the typical PCSG flow channel is that 0.16 mm diameter optical fiber is placed at the middle-edge of flow channel.

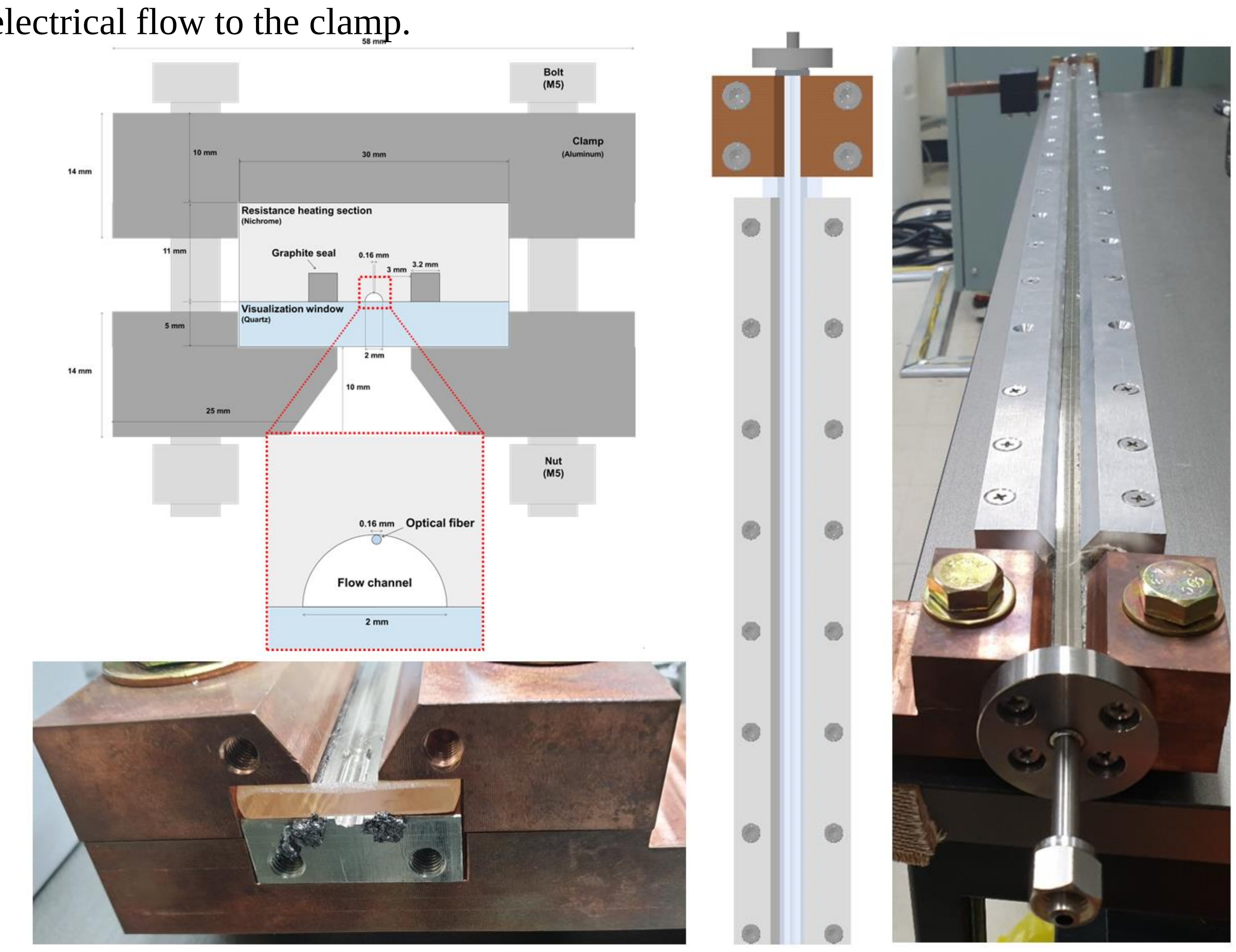
▣ It enables the optical fiber sensor to measure the wall temperature oscillations directly.

▣ The graphite seals are installed symmetrically with respect to the flow channel between the heating section and visualization window since leakage can cause significant measurement error of the flow rate.

▣ With the purpose of the visual observation of dryout instability, the visualization window made of ceramic glasses having a thickness of 5 mm is attached to the heating section.

▣ The resistance heating section and visualization window are physically bonded by the customized aluminum clamp with bolt.

▣ A ceramic fiber dielectric sheets capable of withstanding up to 1600 Celsius degrees are placed between the resistance heating section and the clamp to prevent electrical flow to the clamp.



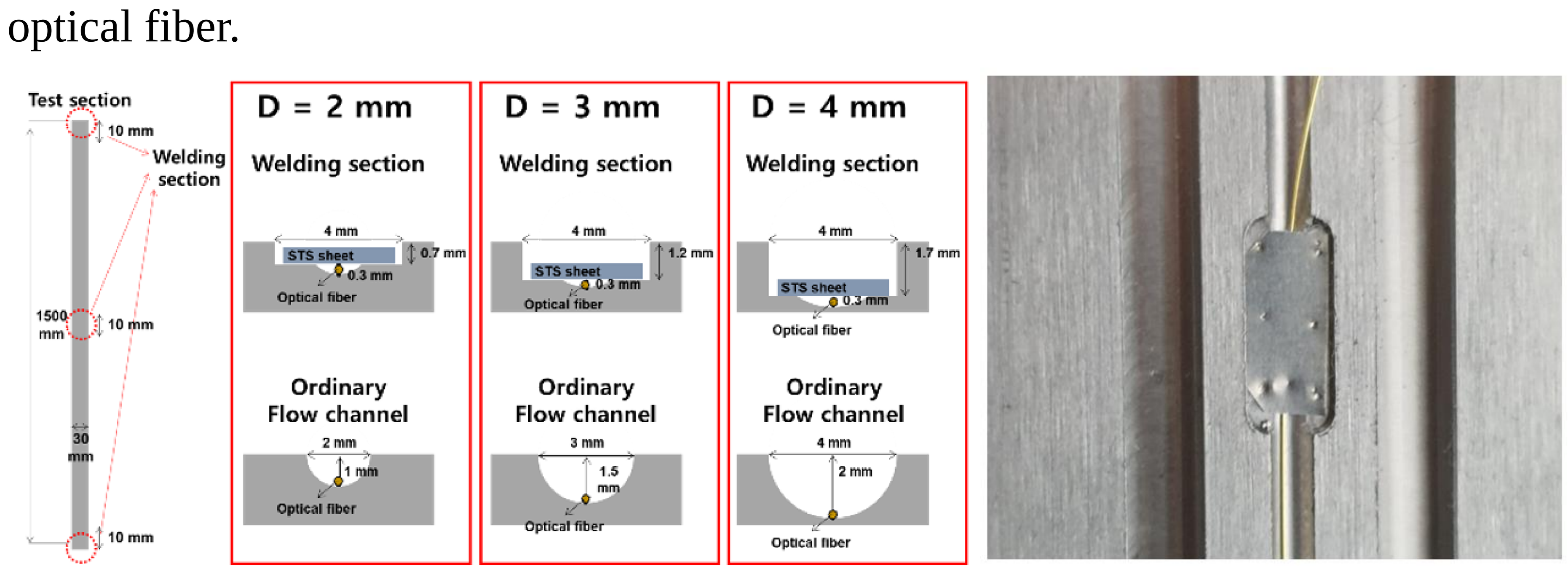
▲Pictures of the test section

3. Installation the optical fiber into the facility

▣ Placing an optical fiber on the wall of a semicircle flow channel with a diameter of 2 mm is one of the issues to be solved for test section design.

▣ A mechanical method using spot welding was used to fix the optical fiber to the heating wall in this study.

▣ The principle is to place the optical fiber between the thin stainless-steel sheet and the flow channel at the 3 locations (inlet, center, and outlet) of the test section along the flow direction, and they are spot welded to limit the movement of the optical fiber.



▲Conceptual diagram of welding section (left) and picture of the welding section (right)